DOCUMENT RESUME

ED 106 073		SE 018 254

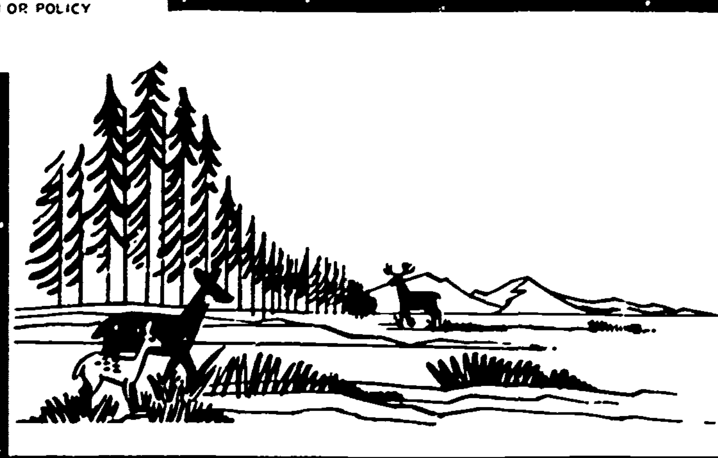
AUTHOR	Halsey, Clifton
TITLE	Minnesota's Soils and Their Uses.
INSTITUTION	Minnesota Univ., St. Paul. Agricultural Extension Service.
SPONS AGENCY	Department of Agriculture, Washington, D.C.
REPORT NO	Bull-383
PUB DATE	[75]
NOTE	33p.; Photographs related to the text may not reproduce clearly
EDRS PRICE	MF-$0.76 HC-$1.95 PLUS POSTAGE
DESCRIPTORS	*Agronomy; Conservation (Environment); Conservation Education; Environmental Education; *Land Use; Natural Resources; Science Education; Secondary Education; *Soil Conservation; *Soil Science
IDENTIFIERS	Minnesota

ABSTRACT

There is an increasing need for land planning and understanding soil is one step toward assuring proper land use. This publication, written by soil scientists and teachers, is designed as a reference for high school teachers. It is designed to be a comprehensive collection about Minnesota soils (although the information can be applied to other areas) that non-experts can readily use. Discussed are topics such as the composition of soil, the importance of soil, soil profiles, soil classification, soil formation, soil variation, soil types, and using the soil. Illustrations, photographs, a diagram of the sulfure and nitrogen cycle, maps, figures, and tables are included. A glossary of soil-related terms used in the text and suggested references are included. (TK)

Minnesota's Soils and Their Uses

By Clifton Halsey,
Extension Conservationist–Soils



GLOSSARY OF SOIL-RELATED TERMS USED IN THE TEXT

acidity, soil acidity – the concentration of hydrogen ions (H^+) in the soil solution.

aeration, soil aeration – the exchange of air in the soil with air from the atmosphere.

aerobic, aerobic organisms – living or acting only in the presence of molecular oxygen.

aesthetic – relating to beauty.

alkalinity, soil alkalinity – the concentration of hydroxyl (OH^-) ions in the soil solution.

amino acids – nitrogen-containing organic compounds which are the chief components of proteins.

anaerobic, anaerobic organisms – living where molecular oxygen is absent.

artificial drainage – a system for removing excess or undesirable surface and/or groundwater, using ditches, underground tile, or both.

aspect, slope aspect – the direction a slope faces.

autotrophic – able to use carbon dioxide or carbonates as a source of carbon and to obtain energy by oxidizing inorganic elements or compounds.

available, available nutrient, available water – the portion of the supply of an element, of a compound, or of water in the soil that can be taken up by plants at rates and in amounts significant to plant growth.

bearing strength – the soil's ability to support weight without shifting or moving.

bedrock – solid rock.

bog – an area of organic soil (peat or muck).

calcareous soil – containing enough calcium and/or magnesium carbonate to be alkaline.

clay – refers to either the submicroscopic mineral soil particles less than 0.002 millimeters in diameter or a soil material that contains 40 percent or more clay, less than 45 percent sand, and less than 45 percent silt.

close-growing or close-sown crops – farm crops such as oats, wheat, grasses, and legumes. Their seeds are planted close together, either randomly scattered or in close rows.

compaction – any process by which soil particles are packed closely together, reducing the space between them and increasing the density of a given volume of soil.

conifers – trees with cones and needle-shaped or scalelike leaves, usually evergreen.

contouring, contour tillage – performing fieldwork at a right angle to the direction of a slope.

contour strips – even-width strips of crops at a right angle to the direction of a slope, alternating close-sown crops such as oats and alfalfa with row crops such as corn.

crop residues – the portions of annual plants left in the field after harvest.

deciduous plants – perennial plants that shed all their leaves each year, usually in the fall.

deposition – accumulated material which was dropped by slowing wind or water.

depression – a low area of terrain surrounded completely by land of a higher elevation that prevents complete surface drainage of water from the low area.

drainage – the removal of surface water or groundwater from land.

drop spillway – a structure made from concrete or a similar material over which water falls to an apron below.

drouthiness – inability of a soil to hold sufficient water for good plant growth.

erodibility – the degree of a soil's susceptibility to removal by wind or water.

erosion – detachment and removal of soil by wind or water.

fertility, soil fertility – soil's level of nutrients available for plant use.

fertilizer – any material added to the soil to supply nutrients for plant growth.

fill – soil deposited in a depression.

filter field, disposal field, drainfield, soil absorption field – an area used for disposing of sewage liquids by placing these liquids in the soil through a system of perforated pipes or loosely spaced tile.

frost boil, frost heave – raised or disintegrated road surface caused by the accumulation and subsequent thawing of ice in soil beneath the road.

granulated – having numerous clusters or aggregates consisting of many soil particles adhering to one another.

granule – a cluster of soil particles adhering to one another and having many characteristics of a single particle.

grassed waterway – a natural or constructed shallow drainageway covered with grass.

gully – a deep channel cut by flowing water from rains or snowmelt.

heterotrophic – able to obtain energy only through decomposing organic compounds.

horizon, soil horizon – a layer of soil approximately parallel to the soil surface and distinctly different from the soil above and below it.

humus – the dark-colored, well-decomposed, more or less stable portion of organic matter in mineral soils.

igneous rock – formed by solidification of molten (extremely hot, liquid) mineral matter.

impermeable, impervious – resistant to penetration by water, air, or roots.

infiltration – the flow of water into the soil.

internal drainage – rate of movement of water through the soil.

lacustrine – deposited in lake water.

leach – to remove materials from soil by dissolving them in water moving downward through the soil.

liming – spreading agricultural limestone or similar material on the soil to reduce the soil's acidity.

loam – the name for soil containing moderate amounts of sand, silt, and clay (7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand).

loess – soil material consisting mostly of silt-sized particles that have been transported by wind.

logarithm – the exponent or symbol that tells the number of times a factor (called a base) occurs in a given product (or number). If $N = b^x$, x is the logarithm of N to the base b. (Example: $1{,}000 = 10^3$; the logarithm to the base 10 of 1,000 is 3.)

macronutrient – a chemical element necessary in relatively large amounts for plant growth.

manure – animal excrement with or without bedding or litter.

micronutrient – a chemical element necessary in very small amounts for plant growth.

microorganisms – forms of life too small to be seen with the unaided eye.

mine tailings – waste materials from mined mineral processing.

mottle – spots of color different from the color of most of the material in a soil horizon.

mulch – a layer of plant residues or other material on the soil surface.

open ditch – an uncovered channel constructed to convey drainage water.

organic matter – the part of the soil consisting of dead plant and animal material.

organic soil – a soil containing more than 20 to 30 percent organic matter.

outwash, glacial outwash – material carried by glaciers and later sorted and deposited by water flowing from the melting ice.

overflow – water which periodically flows from higher ground to flood a lower area.

oxidation – combination of a chemical with oxygen.

parent material – the unconsolidated mineral or organic material from which the soil profile is formed.

pasture – an area established for animals to graze.

peat – soil material primarily consisting of slightly to partially decomposed plant material which has accumulated under conditions of excessive water.

percolation – downward movement of water through soil.

percolation rate – the rate at which water moves downward through soil.

permeability – a soil's ability to allow water and air to move through it. Permeability is measured as the rate of flow of water through a unit area in unit time under specified temperature and hydraulic conditions.

pH – a numbered expression of the acidity or alkalinity of a soil; the common logarithm of the reciprocal of the hydrogen ion concentration of a solution.

plant nutrient – an element essential to the life and growth of a plant and used by it in elaboration of its food and tissue.

plasticity – the ease with which a portion of soil can be molded or reshaped.

ponded – kept or held in an undrained or slowly draining depression.

pore space – the fraction of the total space in a volume of soil not occupied by solid particles.

porosity – the percentage of total volume of soil not occupied by solid particles.

practice – a customary way or method.

profile, soil profile – a vertical cross section of soil through all its horizons from the surface into the parent material.

reaction, soil reaction – the degree of a soil's acidity or alkalinity.

rangeland – large areas of native grasses used for grazing livestock.

riverwash – unproductive soil deposited by streams and subject to shifting when it's flooded.

rotation, crop rotation – growing different crops in recurring succession on the same land.

row crop – a crop planted in rows so that the soil between the rows may be cultivated.

runoff, surface runoff – the portion of rain and snowmelt water that flows over the surface of the land.

sand – individual soil particles having a diameter between 0.05 and 2.0 millimeters.

seepage – water escaping through or emerging from the surface of the soil.

silt – individual soil particles having a diameter between 0.002 and 0.05 millimeters.

slope – the incline of the surface of a soil from level.

strip crop – having a systematic arrangement of strips or bands of different crops to reduce wind or water erosion.

structure, soil structure – the combination or arrangement of individual soil particles into units or groups of particles.

subsoil – the soil horizon (called B horizon) beneath the layer of darker-colored topsoil. It does not include the altered or unaltered parent material or underlying layers unlike the parent material.

surface inlet – a surface opening to an underground tile to help remove surface water; much like a storm sewer.

terraces – ridges and channels constructed across sloping land surface on or at a slight angle from the contour to prevent erosion by diverting surface runoff to a prepared outlet.

texture, soil texture – the relative proportions of various sizes of individual grains in the soil. It refers to the proportions of sand, silt, and clay.

till, glacial till – unlayered soil material which was deposited directly by melting glaciers.

tillage, tilling – digging and loosening the soil in preparation for planting or to control weeds.

tilth – the physical condition of the soil affecting the soil's ease of tillage and fitness for the growth of a specified plant or sequence of plants.

topography – the shape of an area's surface.

topsoil – the darker surface layer of soil, often the plow layer.

undulating – having a wavy appearance.

watershed – all the land surface from which water drains into a common outlet.

water table – the surface of groundwater or the level below which the soil is saturated with water.

windblown – transported and deposited by wind.

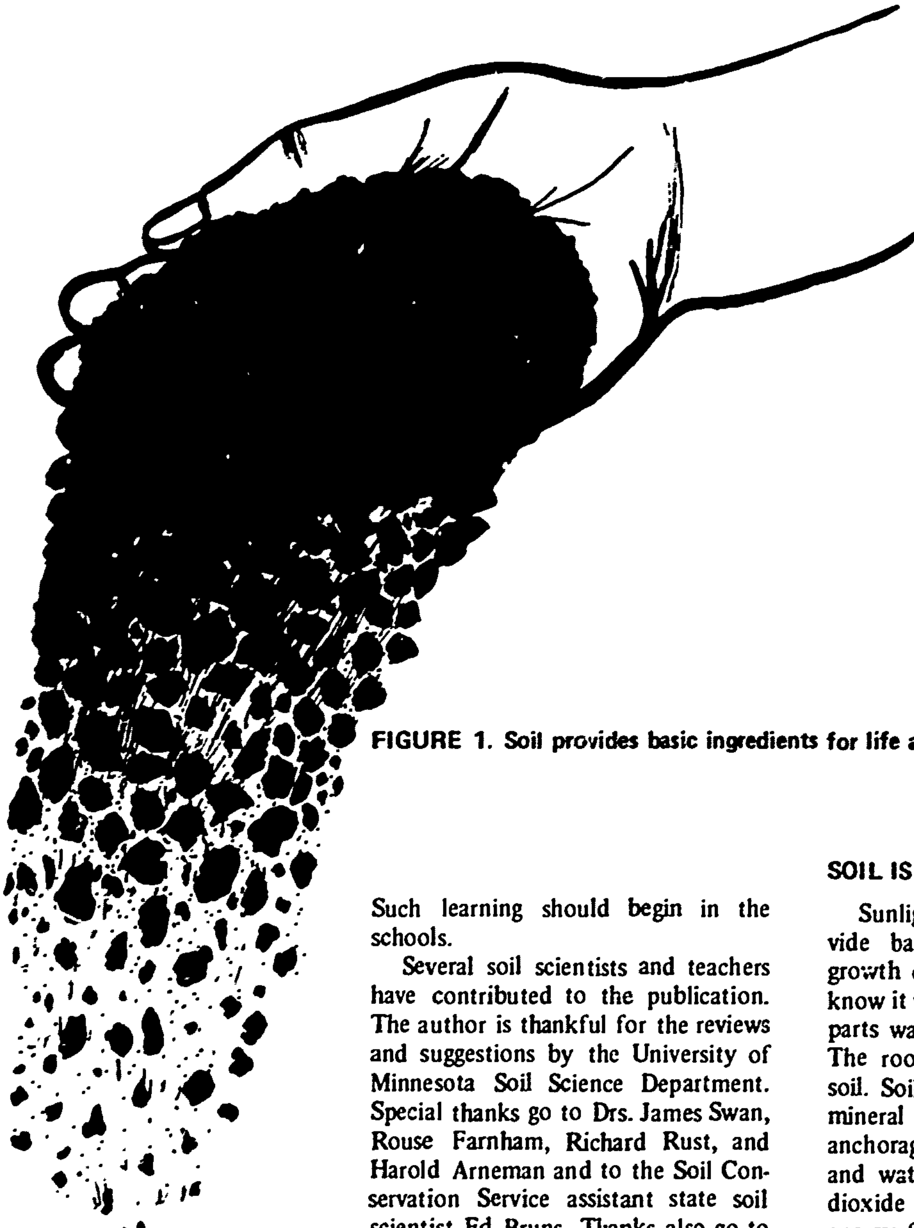


FIGURE 1. Soil provides basic ingredients for life and growth of all living things.

FOREWORD

Minnesota's Soils and Their Uses is a reference for high school teachers. It's designed to be a comprehensive collection of technical knowledge about Minnesota soils that nonexperts can readily use. There is an increasing need for land use planning in the state. Minnesotans need to know about the state's soils to assure proper land use. Such learning should begin in the schools.

Several soil scientists and teachers have contributed to the publication. The author is thankful for the reviews and suggestions by the University of Minnesota Soil Science Department. Special thanks go to Drs. James Swan, Rouse Farnham, Richard Rust, and Harold Arneman and to the Soil Conservation Service assistant state soil scientist Ed Bruns. Thanks also go to Ronald Clendening and Charles Burnham of the Coon Rapids Junior High School science department who reviewed the manuscript and suggested improvements.

The Soil Conservation Service and the Minnesota Highway Department provided many of the photos.

Finally, the author thanks the publications editors and artists of the University of Minnesota Agricultural Extension Service for their help with this publication.

SOIL IS IMPORTANT

Sunlight, air, water, and soil provide basic ingredients for life and growth of all living things. Life as we know it would not exist if one of these parts was missing. Let's consider soil. The roots of almost all plants are in soil. Soil furnishes plants with water, mineral nutrients, and support or anchorage. Plants – using elements and water from the soil, the carbon dioxide from the air, and radiant energy from the sun – produce food on which all animals depend.

Soil also provides:

- homes for microscopic organisms and for many larger animals;
- minerals that are carried into lakes and streams to nourish aquatic life;
- the foundation, the minerals, and the construction materials needed for many of man's activities and structures.

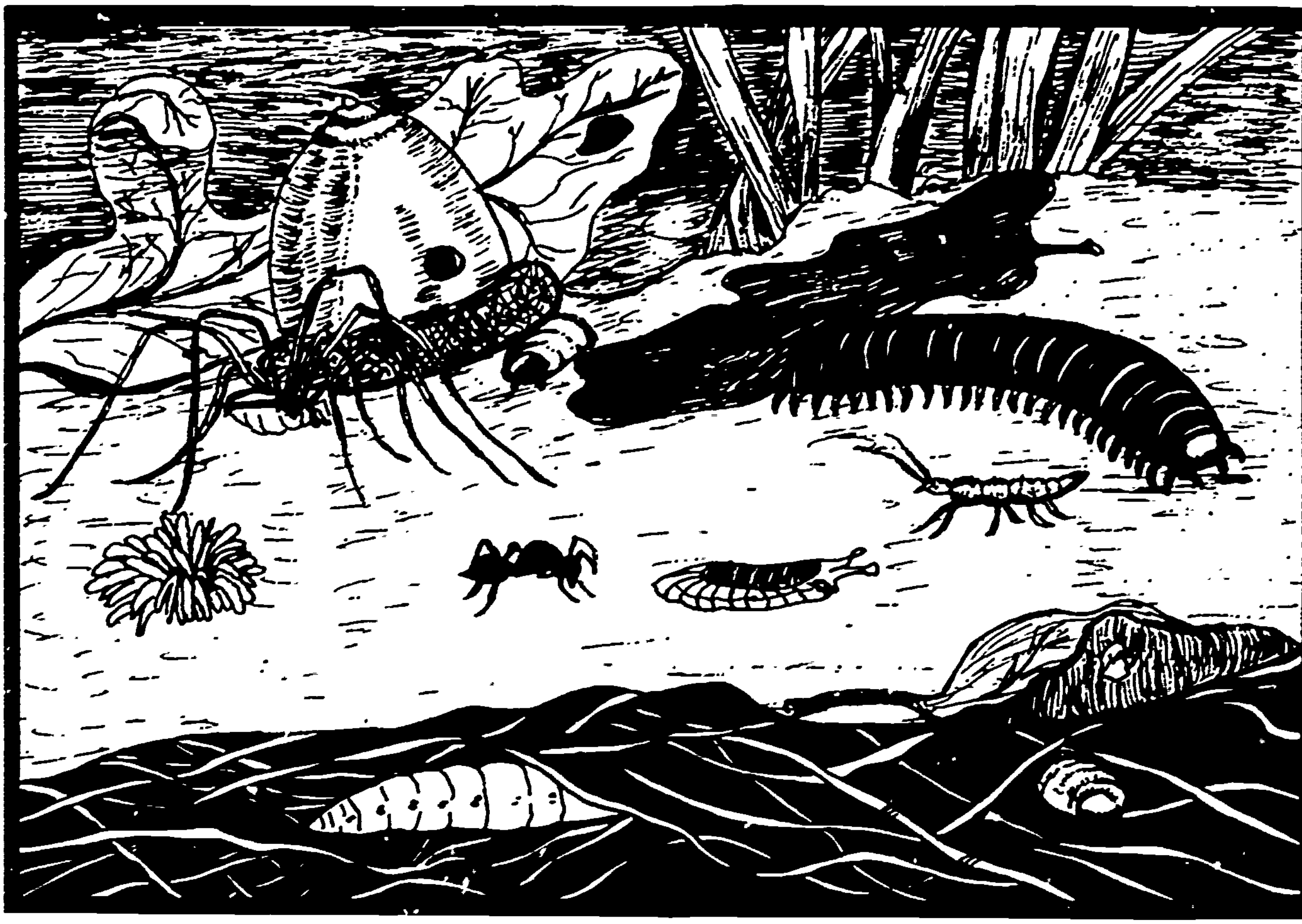


FIGURE 2. Moist, fertile soil contains many living things.

COMPOSITION OF SOIL

Most people think soil is finely ground rock. A closer look reveals that soil is much more. It has depth, and from the surface downward, soil may be different in color, in size of particles (texture), and in other characteristics. Soil contains microorganisms, fungi, crawling animals, and insects. The soil contains oxygen for these animals to use. Soil also contains water.

A surface soil good for most plants contains about 45 percent (by volume) of mineral matter particles. Another 5 percent is dead and decaying plant and animal material. The remaining half of soil is space occupied by gases and liquid.

Mineral matter

Let's take a closer look at the mineral portion of soil. Depending on the soil's texture (coarseness or fineness), we may see small stones or gravel particles. These are rock fragments. If their corners are rounded, these fragments have been rolled and worn by flowing water and/or glaciers. Particles of sand (which can be seen without magnification) are mostly original mineral particles. These particles were once part of massive rock. Smaller particles individually visible through a microscope are called silt. The finest particles, clay, are visible only through an electron microscope. Some silt particles, like sand, are original primary mineral particles from weathered rock. The rest of silt and most of clay are secondary minerals. These minerals have been chemically and physically changed after thousands of years.

Animals

Moist, fertile soil contains many living things. The following list[1] shows the number and variety of microorganisms that may be found in 1/4 teaspoon of fertile soil.

- 50 nematodes – microscopic parasites and predators;
- 62,000 algae – microscopic plants;
- 72,000 amoebae;
- 111,000 fungi;
- 2,920,000 actinomycetes;
- 25,280,000 bacteria.

Bacteria, alone, in 1 acre of soil is estimated to weigh 1 ton or more. (The average weight of an acre of topsoil 7 inches deep is 1,000 tons.) One acre of moist, loam soil may contain more than a million earthworms. These earthworms weigh a total of more than 1,000 pounds (1 acre contains 43,560 square feet).

---

[1] Waksman, Selman A., 1952. SOIL MICROBIOLOGY. John Wiley, New York.

This chart lists the more important organisms in soil.

Kinds of soil organisms and their roles

- I. Animals
  - A. Macroorganisms
    - 1. Feed largely on plant materials.
      - Small mammals — ground squirrels, gophers, woodchucks, mice.
      - Insects — springtails, ants, beetles, grubs, etc.
      - Millepedes, sowbugs, mites.
      - Earthworms, slugs, snails.
    - 2. Mostly predatory (eat living animals).
      - Moles, shrews.
      - Insects — many ants, beetles, etc.
      - Mites, in some cases.
      - Centipedes.
      - Spiders.
  - B. Microorganisms
    - Predatory, parasitic, or feed on plant residues.
      - Nematodes, protozoa, rotifers.
- II. Plants
  - Roots of higher plants.
  - Algae — green, blue-green; diatoms.
  - Fungi — mushrooms, yeasts, molds.
  - Actinomycetes.
  - Bacteria.

Microorganisms eat and decompose plant and animal material. Decomposition releases this material's nutrients for re-use by higher and lower forms of life. Remaining organic matter (humus) increases the soil's infiltration, aeration, water-holding capacity and resistance to erosion. Almost all nematodes are microscopic. A few feed on the roots of higher plants such as potatoes and carrots. Some predatory nematodes eat other animal life. A third group feeds on decaying organic matter.

Protozoa are one-celled, microscopic animals. They are grouped according to their development. The flagellates are most common in soil, followed by amoebae and then ciliates. Most soil protozoans feed on dead organic materials. Some may feed on bacteria.

Rotifers are also microscopic animals. They live in moist soils and are especially abundant in swampy land. Their importance in soils is unknown.

Millepedes, sow bugs, mites, slugs, and snails feed mostly on relatively undecomposed plant tissue. Millepedes are especially active in peat soils.

Earthworms are very important to soil. They take in the soil, digesting both organic and mineral soil particles. In loam soils high in organic matter, earthworms eat as much as 15 tons of soil per acre each year. This activity helps plants in several ways. It increases the soil's content of decay-resistant or residual organic matter (humus), makes more plant nutrients available, and increases soil aeration and drainage.

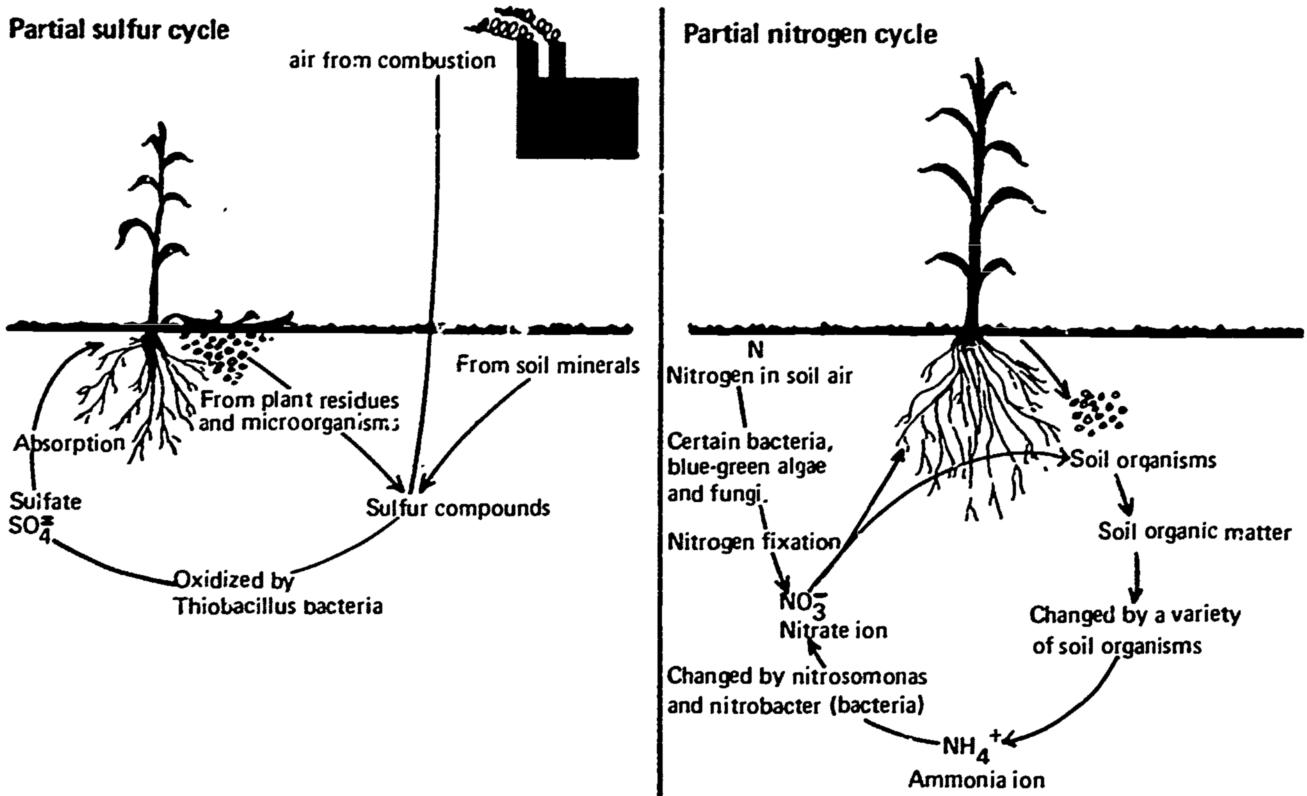
Vegetable matter

Plant life in soil is even more important than animal life, especially in its final decomposition of the organic matter. Animals in soil perform much of the initial decomposition; microflora carry it much further.

Algae are most numerous near the soil surface. Grasslands and waterlogged soils are favorite sites for blue-green forms, and diatoms are abundant in old gardens. Algae contribute some organic matter to soil. *Fungi* transform organic matter into fungal tissue, especially in acid forest soils. *Actinomycetes* are especially numerous in neutral mineral soils high in organic matter. They are able to use the more resistant and complex residual organic parts in the soil, reducing these fractions to simpler compounds.

One billion to three billion *bacteria* may be in 1 gram of soil. Bacteria are very small, less than 0.005 millimeters in size. Smaller bacteria are about the same size as individual clay particles. When growing conditions are favorable, the bacteria multiply on soil particles. There they form colonies in the shapes of mats, clumps, and filaments. Autotrophic bacteria obtain their energy by oxidizing ammonium, sulfur, and iron compounds. Their carbon comes from carbon dioxide. Autotrophic bacteria are important because they convert nitrogen and sulfur to compounds used by higher plants. Heterotrophic bacteria derive their energy and carbon from soil organic matter. Bacteria are perhaps the most important form of life in soil because they are responsible for three life-sustaining transformations: nitrification (nitrogen oxidation); sulfur oxidation; and the fixation of nitrogen from the soil air.

Plant roots are an important source of organic matter in soil. They are the



(Adapted from Nature and Properties of Soils, page 468.)

(Adapted from Nature and Properties of Soils, page 440.)

FIGURE 3. Soil microorganisms recycle plant nutrients.

ultimate food source for much soil life. Even when the roots are living, they actively dissolve nutrients and excrete amino acids at their surfaces. The number of organisms may be from 10 to 100 times as great in the immediate root zone as in other parts of the soil.

Soil air

Plant roots and other soil life need air for respiration. These roots also release carbon dioxide. Gases in the soil spaces (these spaces are called pores) must move freely so life can exist in the soil. The pores in soil are a maze of small open spaces. Part of these spaces is occupied by water.

Air in the soil is not pure. Moist soil is nearly saturated with water vapor. The carbon dioxide content in soil air is several hundred times greater than that in the air above ground. Oxygen may be no more than 10 to 12 percent in soil air. It is about 20 percent in the air we breathe. Soil air also contains ammonia, sulfur dioxide, and other gases not found in the air above ground.

Poorly aerated (ventilated) soils contain reduced compounds (compounds from which oxygen has been removed) poisonous to higher plants. These reduced compounds form when anaerobic organisms take oxygen from oxides for their own use. Poor aeration can be caused by flooding, poor internal drainage, and compaction.

FIGURE 4. Flooding restricts the amount of air in the soil for the growth of corn (SCS photo).

Soil water

Soil water is complex. It is not pure, but is a solution containing dissolved gases, plant nutrients, living things, and occasionally compounds toxic to plants. Too much water in soil pores restricts the amount of air for plant growth. However, too little water is also restrictive.

Soil water may be measured in terms of saturated capacity of the soil to hold water (all pores filled); the amount of water that soil will hold against the force of gravity; and the amount remaining in soil when plants begin to wilt. The most practical measurement is available water, that which can be used by plants at significant rates.

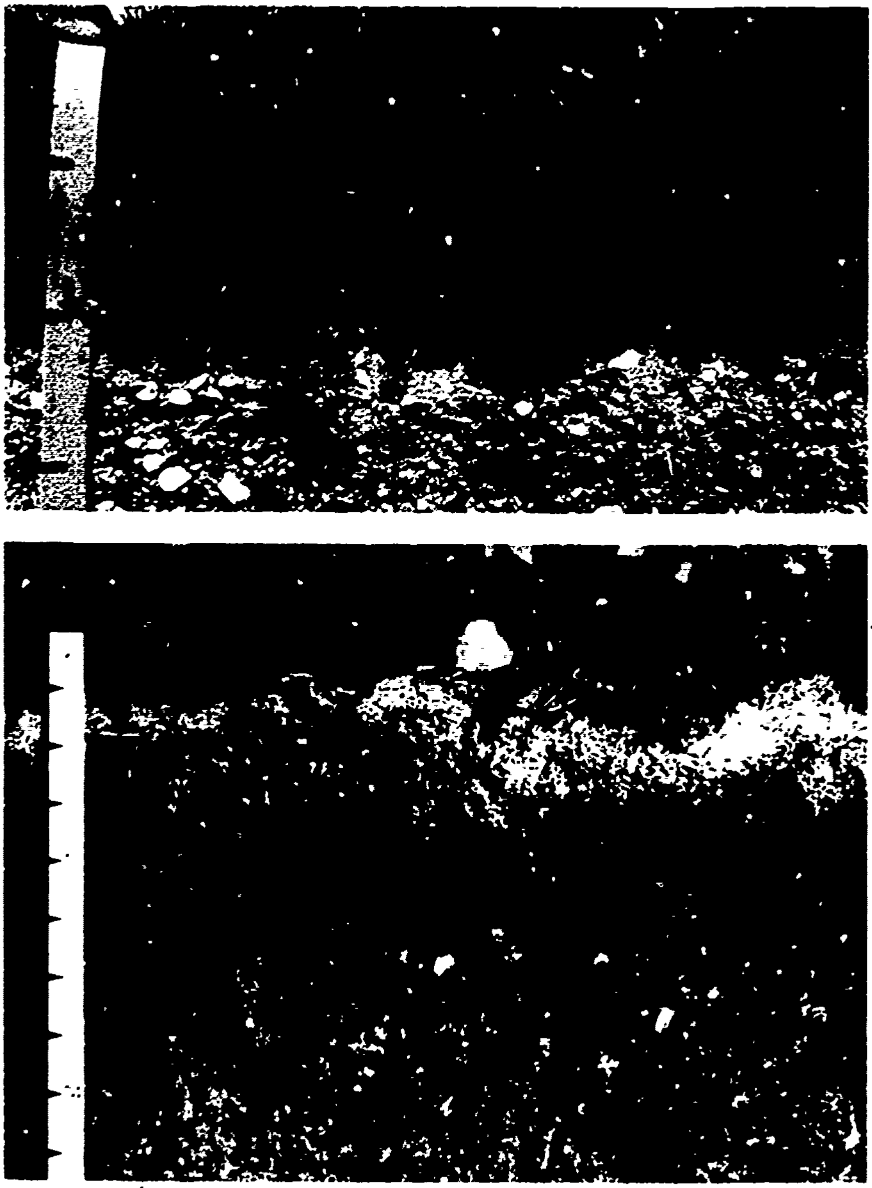
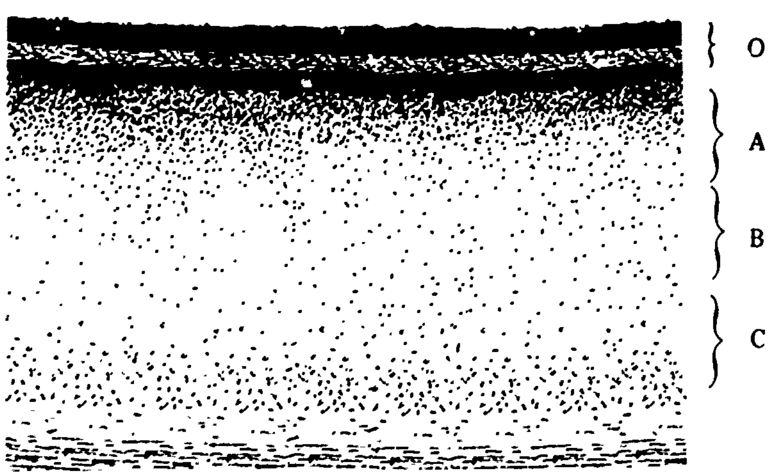


FIGURE 5. Each well-developed soil has its own distinct profile. The top photo shows a very drouthy prairie soil, and the photo above shows a forest soil.

FIGURE 6. (Below) This illustration shows the horizons in a soil profile.



SOIL PROFILES – A LOOK FROM THE SURFACE DOWNWARD

Soil has depth as well as surface area. Soil is classified according to particle size (texture), organic matter, color, and other characteristics from the surface down to the unchanged parent materials or to other geologic structures or deposits below the soil. The arrangement of these soil components is the "soil profile." Individual layers in the soil profile are called "horizons." Each well-developed, undisturbed soil has its own distinct profile. These profiles are used to classify soils according to their suitability for various uses.

The upper layers of soil are usually darker than lower ones because the upper layers have accumulated organic matter. These layers are called "topsoil." Lower layers are "subsoil." Subsoil usually has three bands: an upper transition layer; a middle layer containing materials carried down by water from above; and a bottom layer of nearly unchanged parent material. Soil horizons are described in figure 6.

O horizon – raw and partially decomposed organic material above the mineral soil.

A horizon – surface mineral layers, including the zone of maximum accumulation of decomposed organic matter within the mineral portion and the zone of maximum leaching or removal of clay particles, mineral compounds, and organic matter.

B horizon – the zone of maximum accumulation or deposit of materials removed from the layers above.

C horizon – layer of material below the zone of maximum accumulations and not much affected by the soil-forming factors. This layer may be slightly weathered parent material much like the material from which the soil above it was formed, or it may be unrelated material unlike the parent material.

Similar soils in different locations may be identified through detailed descriptions of their profiles. Similar soils in separate locations will respond in the same way to the same uses and land treatments. A Hubbard sandy loam in one location will be as good for a septic tank drainfield as the same soil in another location. A Floyd silty clay loam in one county will be just as wet for corn and as poor for a septic tank drainfield as the same type of soil would be in another county. Soil scientists name specific types of soil after locations where these soils can be found.

Identification and classification of soils according to physical and chemical characteristics of soil profiles helps in planning land use management.

SOIL CLASSIFICATION

Soils throughout the United States are classified in a comprehensive system developed by the U.S. Department of Agriculture. The most recent revision of this classification system, called the *Seventh Approximation*, was adopted in 1960. Classification is based on soil properties in the field properties that can be measured quantitatively. Color, texture, structure, organic matter, type of clay, pH value, soil depth, internal drainage, and chemical compounds are some properties that may be considered.

Soil scientists record their findings on aerial photographs. Soil survey reports have been printed for more than 52 of the 87 Minnesota counties. They may be found in libraries or at offices of the Agricultural Extension Service or soil and water conservation districts. Some older reports are out of print. Recent survey reports may be purchased from the Superintendent of Documents in Washington, D.C. These reports describe individual soils in great detail. Recent reports also include information about the suitability, use, and management of soils for agriculture, forestry, wildlife, roads, buildings, and recreation. Soil survey reports are an excellent source of technical information for planning land use.

FIGURE 7. This soil survey map shows detailed soil characteristics of a small portion of Fillmore County in southeastern Minnesota.

SOIL FORMATION IN MINNESOTA

Minnesota has 80,000 square miles of land and 4,000 square miles of water, including 15,000 lakes. There are hills and valleys, rivers and peat bogs, rock outcrops and waterfalls. We crop fertile farmlands, quarry granite and limestone, mine iron ore, harvest the forests, and hunt the wildlife. The soil varies greatly from one part of the state to another.

Much of the northwestern area is nearly level with a fine-textured, dark-colored soil. Although part of it floods and its excess water drains away slowly, northwestern Minnesota is a fertile agricultural area.

Extreme southeastern Minnesota is rolling to hilly. Water runs off rapidly and can erode the soil. This area's silt loam soils are well-drained, and the gentler slopes can produce bountiful crops. Steep slopes are suitable only for forests and wildlife.

In some parts of the state, soils differ greatly within short distances. Changes in the slope, internal drainage, and texture may be very abrupt or sudden. There are short, steep hills with ponds at the bottom. There are sloping lands with medium-textured soils adjacent to very sandy, nearly level areas.

Why is there such variability in the soil?

Most of Minnesota's present landscape was shaped by continental glaciers. The last glacier melted about 11,000 years ago. These glaciers formed during long periods of cold weather as snows accumulated to depths of many thousands of feet. The extreme weight of the accumulation compacted the bottom layers into ice. This ice became somewhat fluidlike similar to cold syrup and spread out in all directions over the continent. The thick ice mantles slowly moved over hills and valleys, mountains and plains, scraping and gouging enormous amounts of rock and soil ranging in size from house-sized chunks to fine dust. The basins of many Canadian border lakes are a result of this gouging. Glaciers entering Minnesota from the northwest carried limestone materials from southern Canada. Glaciers flowing from the northeast removed and crushed bedrock and other materials from Ontario and northeastern Minnesota.

The glaciers melted as the climate warmed. Remaining rock and mineral debris were left in varying arrangements of sorted and unsorted materials. South central Minnesota was mostly an undulating expanse of mixed, unsorted materials deposited directly as the ice melted uniformly. At intervals, belts of hills interrupt this expanse. These hills consist of glacial debris formed by temporarily stalled edges of the retreating glaciers.

Large quantities of water were discharged at the edges of the melting glaciers. These glacial streams deposited well-sorted layers of sand and gravel (called "outwash") along the major rivers such as the Minnesota and Mississippi. They also created large, flat sandy plains. The glaciers, acting as dams, created large lakes such as glacial Lake Agassiz, which included the area now called the Red River Valley. The lake bottom sediments are fine-textured clay materials. The lake edges or beaches are sandy or gravelly materials.

Southeastern and southwestern Minnesota have extensive areas of silty materials (called "loess") which were blown about by the wind before vegetation became established.

The differences in the materials – limestone deposits to nonlime bedrock, particle sizes from house-sized boulders to submicroscopic clay, and heterogeneous mixtures of particle sizes to well-sorted sizes of particles – produced a wide variety of *parent materials* from which Minnesota soil was formed. Understanding these differences will enable the user – home owner or road contractor – to employ the soil to the best advantage of everyone.

The *climate* where soil is forming greatly influences the speed of formation. Running water and extreme changes in temperature cause physical weathering or disintegration of mineral particles. Alternate freezing and thawing of water in cracks as well as

FIGURE 8. Continental glaciers covered much of North America. (From Minnesota's Rocks and Waters, page 155.)

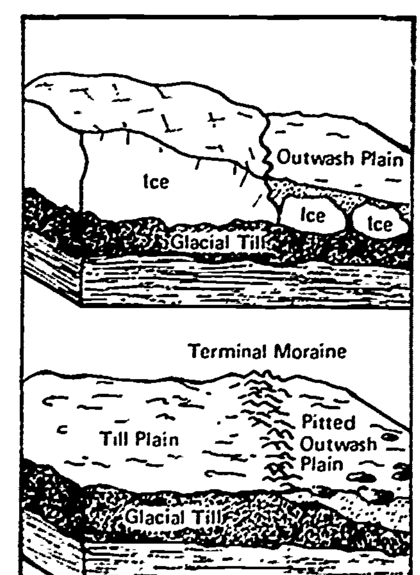


FIGURE 9. The melting glaciers left mineral debris in varying arrangements.

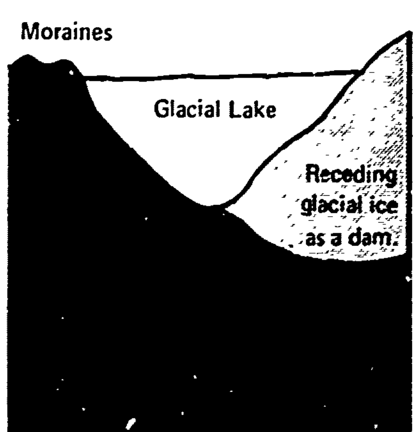


FIGURE 10. Glaciers, acting as dams, created large lakes.

heating and cooling of rocks are examples of temperature effects. Drier climates favor prairie grasses rather than forests. Warm temperatures hasten the decay of organic matter. Heavier precipitation increases movement of elements from the surface to the subsoil. It also increases the rate of erosion of the surface of sloping soils to more level areas.

Topography and climate are closely related factors influencing soil formation. The steepness of a slope affects the amount of water that soaks into the soil and that runs off, possibly carrying surface soil with it. Hilltops usually have shallower topsoil for this reason. The direction of slope ("aspect") affects the temperature near the soil surface. North- and east-facing steeper slopes are cooler and favor forest vegetation. Warmer south- and west-facing slopes favor prairie vegetation. Level areas having slow internal drainage accumulate organic matter because the water in the soil inhibits bacterial oxidation and decomposition.

Native vegetation interacts with climate and topography to form soil. The most obvious effect is on the soil's organic matter content as indicated by soil color. Although drier climates favor prairie grasses, fire was important in restricting expansion of the forest into prairie land. Roots of grasses are short-lived, and organic matter formed from them accumulates to develop a deep, dark topsoil. Roots of the forest trees are long-lived; it is mostly the leaves and dying branches that form organic matter on the surface of the soil. The decaying remains of forest vegetation causes soil water near the surface to become more acid. This acid solution dissolves chemical compounds and organic matter and carries them down into the soil. Therefore, little accumulation of organic matter results in surface soil underneath forest vegetation.

Time, in terms of hundreds to thousands of years, is required to form soil. Older soils are more developed than younger ones formed under the same conditions.

These factors – parent material, climate, topography, vegetation, and time – are "soil-forming factors."

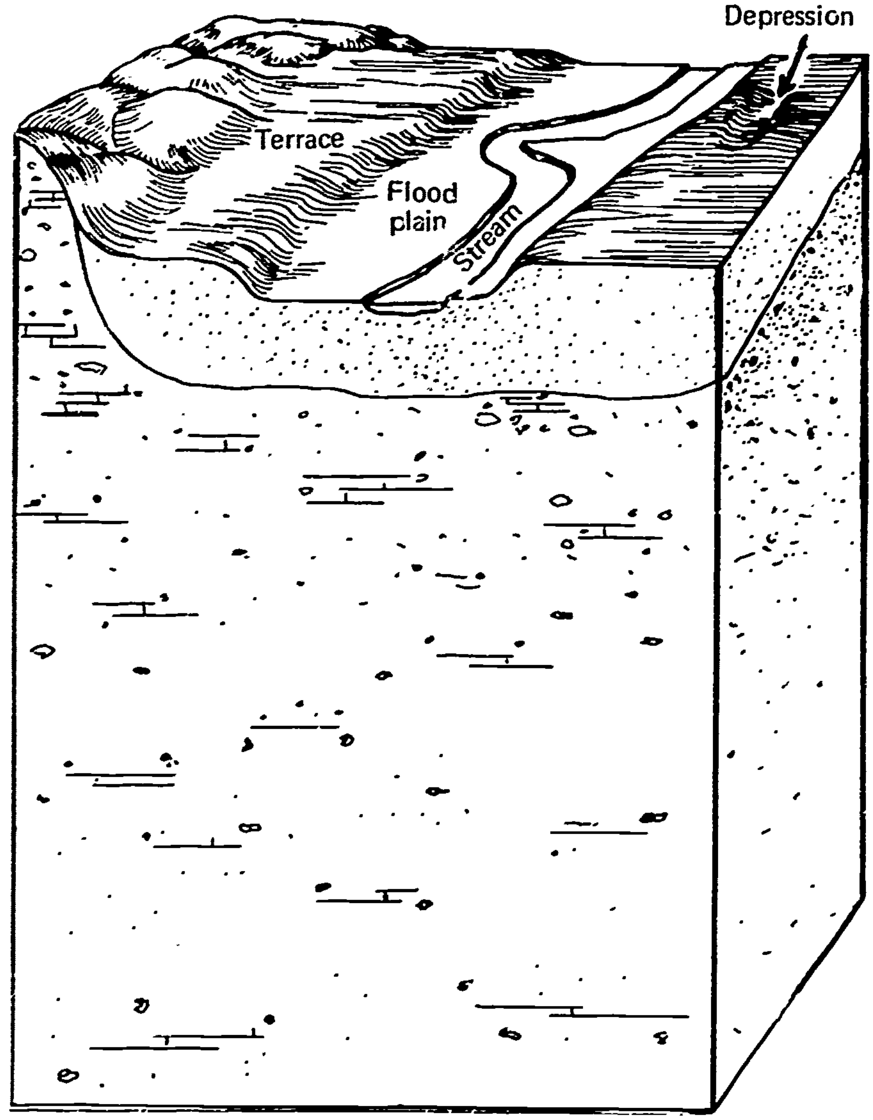


FIGURE 11. Topography is an important soil characteristic.

SOIL DIFFERS GREATLY FROM PLACE TO PLACE

Soil varies greatly from one location to another, sometimes within a few feet. Changes in parent material and topography are responsible for much of the variation over short distances. Time, climate, and native vegetation cause changes from one region to another.

Topography

One of the first features we notice about landscapes are their topography. Some are nearly level. Most land in Minnesota slopes. Slopes may vary in steepness, length, and aspect (direction they face). Topography may be even or uneven and irregular. The elevation, as related to the surrounding area (top of the hill, hillside, or bottom), is important, too. The amount of slope or *steepness* of the soil is important when deciding how soil can be used.

Slope may be expressed in several different ways. Tables 1 and 2 (next page) illustrate them.

Table 1. Expression of slope.

Regular topography	Irregular topography	Percent slope	Letter designation
Nearly level		0-2	A
Gently sloping	Undulating	2-6	B
Moderately sloping	Rolling	6-12	C
Moderately steep	Hilly	12-18	D
Steep		18-25	E
Very steep		25 or gre	F

Table 2. Expression of slope.

Slope ratio	Percent slope	Degrees
1:1	100	45
2:1	50	26
3:1	33 1/3	18
4:1	25	14

Slope percentage is the vertical change in elevation between two locations divided by the horizontal distance between them and multiplied by 100. Slope percentage is the change in feet of elevation between two points 100 feet apart. Soil scientists designate letters to represent the ranges of slope. "Slope ratio" (a term used by engineers) is the ratio of the horizontal distance between two points to the vertical change in elevation between them.

Steepness affects: the amount and speed with which water runs off the soil; the amount of water remaining to soak into soil and water-bearing geologic formations; the depth of soil on the slope; and the amount of natural and man-accelerated erosion. If slope percentage is doubled, the soil lost by erosion is about 2 1/2 times as much.

Length of the slope is important because it affects erosion. The longer the slope, the more water flows over the lower part of the slope. If slope length is doubled, soil loss per unit area increases by about 1 1/2 times. Larger amounts of water can carry more soil until it reaches the point when soil is dropped on the lower slope or, if the water is concentrated in narrow channels, gully erosion occurs.

Direction of slope influences soil temperature and soil water available for plants. South and west slopes face the sun for longer periods and during the warmer part of the day. Therefore, they are warmer and drier than north and east slopes. The kinds and qualities of plants growing on these sites will reflect these differences.

Uniformity of the slope is a combination of direction, length, and steepness. Uniformity influences the types of soil-conserving practices farmers can use.

Relative elevation of the land compared to the surrounding area influences flood hazards. Plant species vary in their tolerance to flooding in terms of the season, duration of submersion, and frequency of flooding. Flooding also affects the land's suitability for wildlife and for structural uses such as homes and streets.

Watersheds are a result of topography. A watershed is the land area which contributes all the runoff water flowing into a body of water or past a certain point (more specifically, through the cross-sectional area) of a stream, ditch, or other waterway. For example, all the land from which water flows into the Blue Earth River in southern Minnesota is a part of the Blue Earth River Watershed. That river and several others flow into the Minnesota River. Each river receives runoff water from a specific land area because of the directions of slope within the area. Thus, the Minnesota River Watershed consists of numerous smaller watersheds. The Minnesota River Watershed is a part of the Mississippi River Watershed.

Flooding, pollution, and sedimentation into a lake or stream are caused by actions within its specific watershed. Solving these problems frequently involves the entire community within the watershed.

Texture

A very important but less obvious feature of the soil is its *texture*. Texture is the fineness or coarseness of soil. Texture is the relative amounts of the various sizes of mineral particles in the soil. There is a very great range in the size of soil particles. Gravel refers to particles larger than 0.08 (1/12) inch in diameter. Twelve particles of that size laid side by side would make a line about 1 inch long. Clay refers to particles smaller than 0.00008 inch, one-thousandth the size of the smallest gravel particle. It would take more than 12,500 clay particles side by side to form a line 1 inch long. This line would be so thin that it would take more than 250 lines side by side to form a line as wide as a pencil mark. Table 3 shows the relative sizes of soil particles.

A clay particle enlarged 500 times may be as large as the period at the end of this sentence. Sand particles enlarged 500 times could be from 1 inch to more than 3 feet in diameter.

Table 4 shows the sand, silt, and clay content of three Minnesota soils.

The *shape of soil particles* is responsible for many characteristics attributed to soil texture. Gravel particles are usually somewhat rounded. Sand and silt particles may be rounded or quite irregular, depending on how much they have been worn by water or wind. Soil particles do not fit tightly side by side like a stack of blocks or bricks. They are more like marbles of various sizes in a container. Smaller ones fit into the spaces between larger ones; clay particles are in the spaces between sand particles. There is much space (called pore space) between these particles. When the soil is dry, this space is mostly air. When the soil is very wet, the pore space is filled with water.

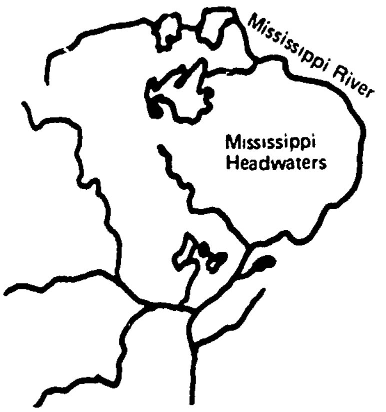


FIGURE 12. (Above) A stream's watershed is all the area from which water drains into that stream.

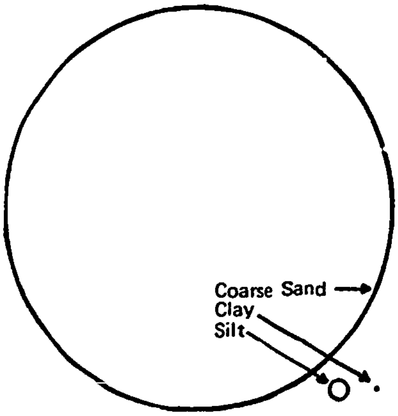


FIGURE 13. (Above) Here are the relative sizes of three kinds of soil particles enlarged about 500 times.

Table 3. Sizes of soil particles.

Particle	Range in diameter of particles in millimeters	Approximate number of particles required to form a line 1 inch long	Range in diameter if enlarged 500 times (in inches)	Range in diameter of particles in inches
Gravel	More than 2	12 or less	More than 40	More than 0.08
Sand	0.05 to 2	12 to 500	1 to 40	0.002 to 0.08
Silt	0.002 to 0.05	500 to 12,500	0.04 to 1	0.00008 to 0.002
Clay	Less than 0.002	More than 12,500	Less than 0.04	Less than 0.00008

Table 4. Percent of sand, silt, and clay in three Minnesota soils.

	Sand	Silt	Clay
Fargo silty clay (Red River Valley)	1.2	48.9	49.9
Zimmerman fine sand (Sherburne County)	93.7	3.0	3.1
Nicollet loam (Sibley County)	40.1	38.0	21.9

The various textures of soil have been arranged in more than a dozen classes, but they may be combined into six groups:

Textural group	Range in percent Sand	Range in percent Clay	Textural Class (More clay ← → More sand)
Fine		40%+	Clay, silty clay, sandy clay
Moderately fine	less sand ↑	more clay ↑	Clay loam, silty clay loam, sandy clay loam
Medium			Silt, silt loam, loam, very fine sandy loam
Moderately coarse			Fine sandy loam, sandy loam
Coarse	85%+		Loamy sand, sand
Organic			Mostly decayed plant material

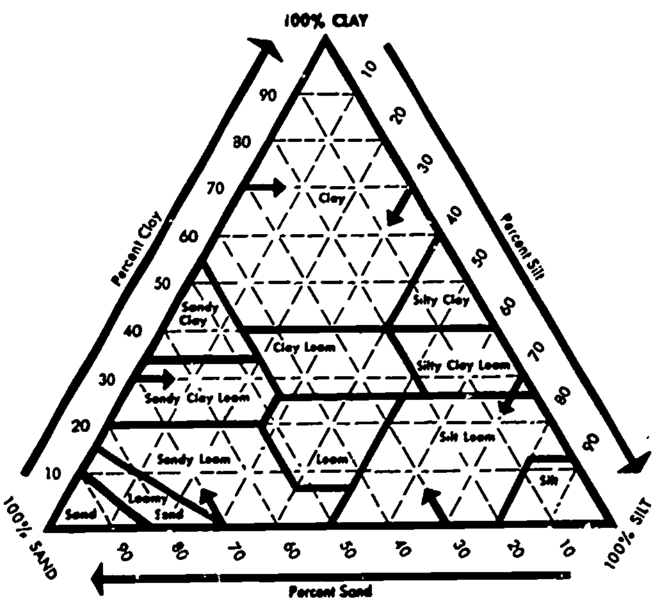


FIGURE 14. A soil's textural class is determined by that soil's respective percentages of sand, silt, and clay. To use this figure, follow the respective percentage lines for sand, silt, and clay to their appropriate intersections with the figure. For example, a soil with 35 percent clay, 30 percent silt, and 35 percent sand is classified as clay loam.

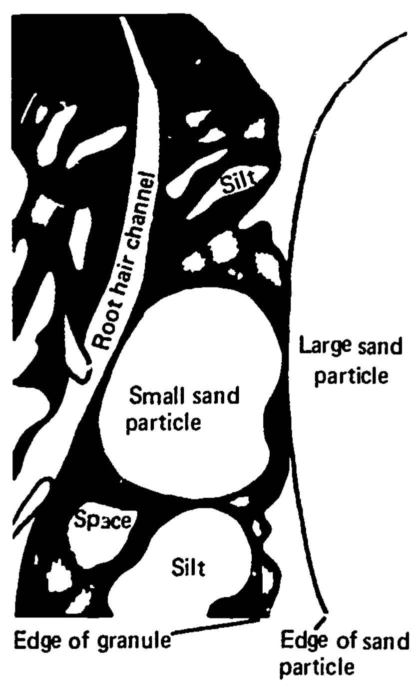


FIGURE 15. Soil has a mixture of particle sizes. This drawing illustrates loam soil enlarged 500 times.

Clay particles are thin, flat sheets. Innumerable clay particles can fit between larger soil particles so that the spaces between larger particles are almost completely filled. The remaining pore spaces, although very numerous, are very small.

Plasticity is a quality of soils containing much clay. Fine-textured soils hold considerable water, which acts as a lubricant between particles. Such soil is easily molded when it is wet. Some clay soils also shrink and swell considerably as moisture content changes. Texture influences the amount and size of air spaces (pores) between soil particles. Pore space influences the:

- speed with which water can move into and through soil (percolation rate, permeability, infiltration rate, internal drainage);
- amount of water the soil can hold for plants (available water-holding capacity);
- amount of air the soil can provide for plant roots (aeration);
- bearing strength of the soil (solid support for heavy loads or weights).

Depth

Soil's depth above bedrock, a water table, or porous sand and gravel greatly influences the soil's suitability for various uses. These effects are described under later headings: Soil air and water; and Using the soil.

Organic matter content

Soil's organic matter content is important for some land uses. Organic matter is the dead remains of plant and animal life. The most obvious effect of organic matter is soil color. The darker the soil, the more organic matter it contains. Organic matter accumulates in soil as a result of the amount and type of vegetation growing in this soil and the rate at which the material forms and decomposes. Soils formed under prairie vegetation are much darker than those developed under forests. This is because a much greater proportion of the prairie grasses is below ground as roots and, therefore, accumulates faster. Wet soils where poor aeration inhibits aerobic decomposition will be much darker than very drouthy soils.

Organic matter holds soil particles together in granules. This makes the soil less erodible, improves soil aeration and porosity, and creates a more suitable seedbed for gardens, lawns, and crops. Organic matter also improves soil's water and nutrient-holding capacity and the amount of nitrogen available for plant growth.

Structure

Structure is the natural arrangement of individual particles in the soil. Very minute organic and mineral particles have a gluelike quality. Clay particles stick together in clusters ("aggregates") of various sizes and shapes. The aggregates' resistance to breaking apart or disintegrating into single particles in water is important. Decay-resistant organic matter increases the aggregates' stability. Surface soils having a granular (grainlike) structure are relatively easy to till and cultivate for crops and gardens. Air and water move more readily through granulated soils. Soils containing relatively large amounts of organic matter and having stable aggregation are more resistant to erosion than similar soils containing little organic matter. Cultivating such soils when they are wet or continually packing them with heavy foot and vehicle traffic destroys the aggregation and reduces these soils' pore space. Plants may not grow as well on compacted soils, and excess soil water drains away more slowly.

Soil air and water

Waterholding capacity may be measured two ways: the amount of water that soil can hold before it is saturated; and the amount that soil can have available for plant use. This section considers the water available for plant use. Available water is influenced primarily by the soil's texture, organic matter content, and depth. The greater the soil's clay content, the more water it will hold. Part of the water contained in the soil is not available to plants; it is held too tightly by the soil, especially by the clay particles. When the water content of a soil is reduced so that only unavailable water is left, the plants wilt. Therefore, the greater the clay content, the more unavailable water the soil will hold. The deeper the soil above bedrock, porous sand and gravel, or compacted layers impenetrable by roots, the more water the total soil can hold for plants. Organic matter in the soil influences the amount of available water in two ways: organic matter holds several times its own weight of water; and it increases granulation and porosity

FIGURE 16. Oak trees on soil with a low available-water capacity grow extremely slowly. These trees may be 100 years old (SCS photo).

which help hold water for plants. Medium-textured soils (loam, silt loam) hold the largest amounts of water available to plants.

The amount of water available for plant use influences the species of plants that will grow well in the soil. Soils with a low available-water capacity are more likely to have natural vegetation tolerant to drouth; prairie grasses are more tolerant than most trees. The quantity of plant growth is greatly affected, also; burr oak trees on Zimmerman sand may be 100 years old and only 20 feet tall.

Available-water capacity is usually expressed as inches of water that a soil 5 feet deep can hold. The texture of soil from its surface to a depth of 5 feet may vary considerably. Hence, surface texture alone does not always indicate the soil's capacity to hold water for plants. Table 5 shows the average amounts of water that soil textural groups can hold for plants.

Available waterholding capacity for soil to 5 feet deep may be expressed as follows: good – more than 9 inches (22.9 cm.); fair – 6 to 9 inches (15.2 to 22.9 cm.), poor – less than 6 inches (15.2 cm.).

Permeability describes the ease with which gases and liquids pass through a soil profile. The sizes and amount of pore space (spaces between soil particles) influence the speed at which water passes through the soil. Sandy soils have relatively large pores, and water can move downward and sideways within the soil rapidly as more water is added. If there are no impervious layers in the soil and the water table is not a factor, most of the water falling on a sandy soil will drain through rapidly. The greater the proportion of fine particles (clay) in the soil, the smaller are the pores and the slower water will percolate or flow through them. Clay is almost impermeable.

The *internal drainage* of a soil is its natural wetness. Internal drainage indicates the ease with which water and air can move and the amount of air available to plant roots. This soil quality affects many structural uses. Internal drainage is a result of several other soil characteristics, most of which have been discussed. They are steepness; relative elevation; texture; structure; and the depth to impervious bedrock, compacted soil layers, water table, or

Table 5. Average amounts of water that soils can hold for plants.

Textural group	Range in inches of water per foot of soil (30.5 centimeters)	
	Inches	Centimeters
Fine (clays)	1.1 to 2.0	2.7 to 5.2
Moderately fine (clay loams)	1.7 to 2.6	4.3 to 6.7
Medium (loams)	2.0 to 2.9	5.2 to 7.3
Moderately coarse (sandy loams)	1.3 to 2.2	3.4 to 5.5
Coarse (loamy sand, sand)	0.2 to 1.4	0.6 to 4.3
Organic (peat)	4.2 to 8.4	10.7 to 21.4

Table 6. Permeability rate and class for several typical Minnesota soil types.

Soil type	Rate of water infiltration inches of water per hour	Permeability class
	More than 20	Very rapid
Zimmerman loamy fine sand (Sherburne Co.)	6 - 20	Rapid
Estherville sandy loam (Sherburne Co.)	2 - 6	Moderately rapid
Barnes loam (Stevens Co.)	0.6 - 2	Moderate
Glencoe silty clay loam (Wright Co.)	0.2 - 0.6	Moderately slow
	0.06 - 0.2	Slow
Fulda silty clay (Swift Co.)	Less than 0.06	Very slow

Table 7. Relationship between soil (internal) drainage condition and soil color.

Soil (internal) drainage condition	Description of subsoil color
Excessive	Coarse texture, yellowish brown
Well-drained	Uniformly brown, dark brown, yellowish brown, dark yellowish brown, or reddish brown throughout the subsoil
Somewhat poor	Mottled upper subsoil, lower subsoil grey or mottled
Poor or very poor	Dull grey or olive color, some mottles may be present

very porous sand and gravel. Internal drainage affects aeration, available water, runoff, and soil color.

Aeration and soil color are discussed in following sections. Table 7 illustrates the influence of soil drainage on the color of subsoil. The color of subsoil can indicate the quality of the soil's internal drainage.

Soil aeration is important for plants, whether the plants are lawns, gardens, or crops. Roots need air for respiration; if insufficient air is present, compounds develop that are toxic to plants. Ferrous oxide, manganese oxide, and nitrites are examples.

Color

Soil color is easily seen and indicates some soil qualities. The darkness of soil and the depth of the dark color reflect the amount of organic matter present. Surface soils under prairie grasses may have a dark color 12 to 14 inches deep. Soils under forests will have a very thin dark-colored surface layer. Soil's natural nitrogen content is closely related to the organic matter content (and therefore color) of the surface soil. The depth of the dark color in prairie soils may indicate the amount of erosion or deposition that has occurred. As surface soil is washed away, the remaining depth of surface soil becomes less. The eroded soil may be deposited at the bottom of the hill where the slope is less steep. As a result, the depth of the surface soil will be increased there. Minnesota surface soils range from black to very light brownish grey.

Soil color, especially that of subsoil, indicates the internal drainage or ease with which water and air may move through the soil. Internal drainage was discussed in greater detail in preceding paragraphs.

Soil contains iron. When the soil is continually well-drained, there is enough air (and consequently oxygen) in the soil to oxidize iron and give the subsoil a yellowish to reddish brown color similar to rusted metal. If the subsoil is continually saturated with water, there is little air in it. Then the iron is not oxidized, but reduced. The soil color is then dull or bluish grey. Soils that are intermittently dry and wet are splotched with grey and red or yellow (mottled). The color of Minnesota subsoils varies from reddish brown to grey.

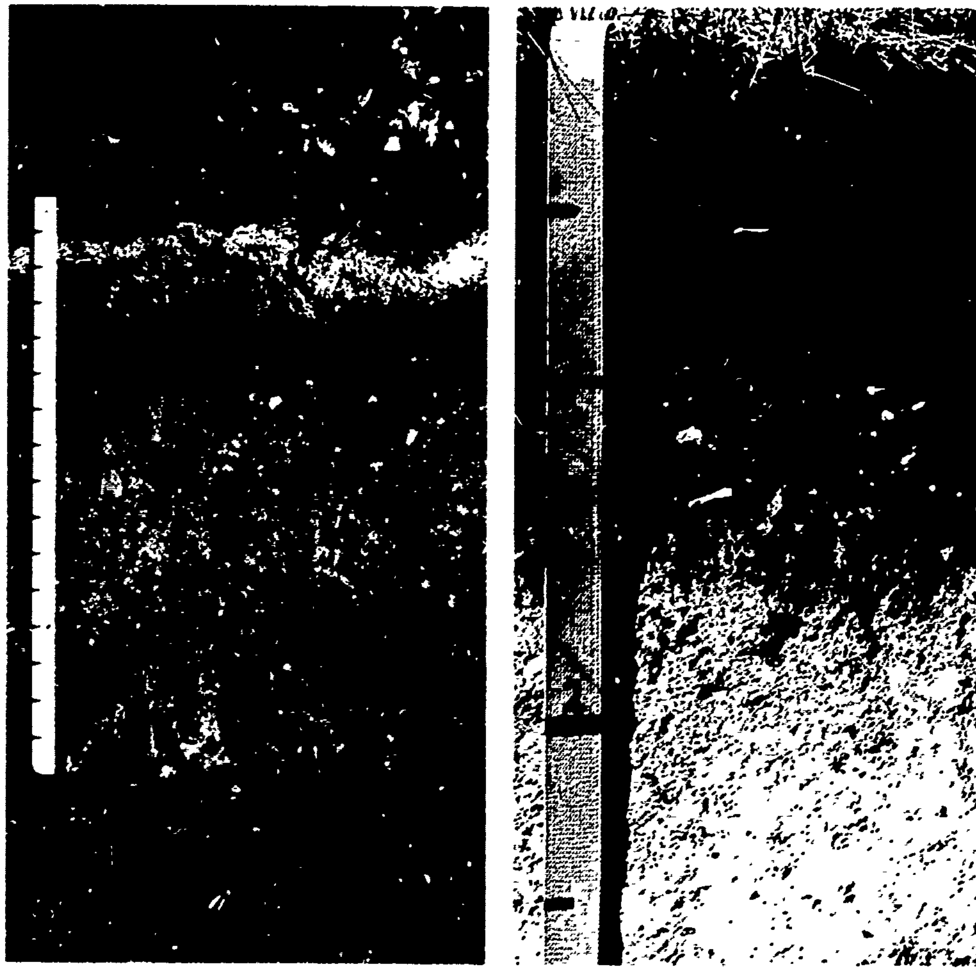


FIGURE 17. The left photo shows a forest soil. Its surface layer is dark-colored and relatively thin. The right photo shows prairie soil. It has a much thicker dark-colored layer.

Surface runoff and erosion

Surface runoff is the rainwater, snowmelt, or irrigation water that runs off the surface of the soil. The steepness of the slope affects how much water can soak into (infiltrate) the soil; the steeper the slope, the faster the water flows downhill, lessening its available time to infiltrate the soil. Vegetative cover impedes the flow downhill, giving the water more time to infiltrate. Soil texture and structure affect infiltration and percolation, also. The coarser the soil and the greater the granulation, the larger the pores in the soil will be and the more rapid will be the percolation. If the soil is not saturated when water is applied, the depth of soil above impermeable layers may also be a factor. It affects the amount of water that can infiltrate before runoff begins.

FIGURE 18. Lack of vegetative cover and a long slope encouraged this erosion during a heavy rain. A grassed waterway would have helped prevent the gully. Some of the eroded soil remains at the bottom of the hill (SCS photo).

Soil's erodibility (the ease with which soil is removed by wind or water) is greatly influenced by the permeability and the structural stability of the surface soil. Well-granulated surface soils resist the beating action of rains that can break up the granules into individual particles and carry them downhill. High levels of residual organic matter promote stable, erosion-resistant aggregates (granules). The same factors that affect surface runoff affect erodibility. Doubling the slope increases erosion by 2 1/2 times. Doubling the velocity of the water theoretically enables the water to move particles 64 times larger, making erosive power 4 times as great and increasing carrying power 32 times. These factors are important wherever land is used, in town or in the country.

Vegetative cover serves as an energy-absorbing canopy. Raindrops strike the grass or leaf litter and run more slowly onto the soil than when these raindrops strike bare ground.

The degrees of erodability are:

Slight: During average conditions of weather and use, there is little chance of excessive erosion. Slopes are gentle; internal drainage is good.

Moderate: Medium or finer textured soils on slopes of 2 to 6 percent and longer than 300 feet could have moderate erosion problems. Shorter slopes may be as much as 12 percent and still have moderate erodibility.

Severe: Slopes exceed 12 percent with soils having a moderately coarse to fine texture.

Wind erosion is closely related to soil moisture content, the amount of vegetative cover on the soil, and the expanse of land not protected from the wind. Large areas without vegetative cover, such as the Red River Valley in the spring, are subject to considerable wind erosion. Drouthy soils, such as the Zimmerman sands in Sherburne County, are noted for their susceptibility to wind erosion. Intensively cultivated peat soils develop into finely divided, light particles that are easily moved by the wind.

Soil reaction — acidity — alkalinity

Soil reaction is the soil's degree of acidity or alkalinity. Reaction refers to the relative amount of hydrogen and aluminum ions and other acid-forming elements compared to the amount of hydroxyl ions and base-forming elements such as calcium and magnesium When the acid- and base-forming ...ements are balanced, the soil is neutral. Soil reaction results from soil-forming factors: parent material and its content of acid- and base-forming elements; the climate as it affects leaching through the soil; the vegetation or crops growing on the soil; and time.

Soil reaction is usually expressed in "pH." The pH scale is logarithmic (see glossary for definition) from 1 to 14. A pH of 7 is neutral, neither acid nor alkaline. A pH below 7 is acid; above 7

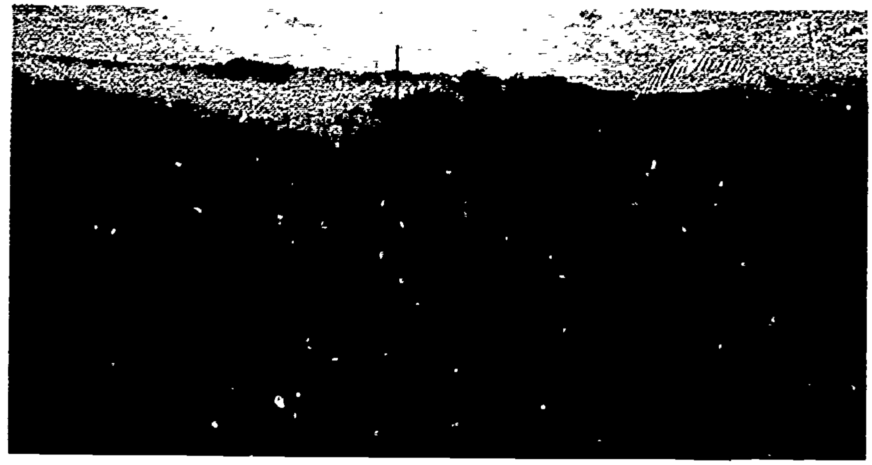


FIGURE 19. (Above) Unprotected dry, sandy soils are easily eroded by wind (SCS photo).

FIGURE 20. (Below) Field shelterbelts and strip cropping help control wind erosion (SCS photo).

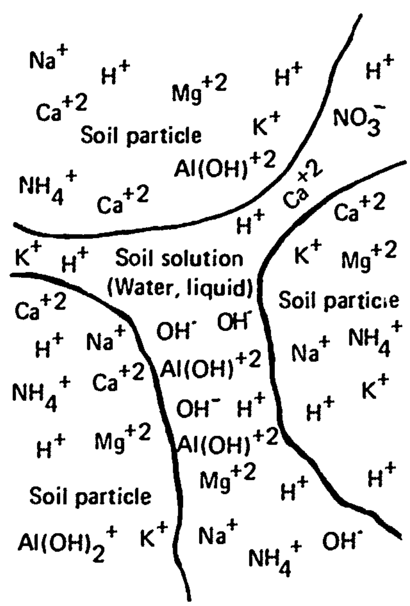


FIGURE 21. Acid- and base-forming ions are in the soil solution and are attached to soil particles.

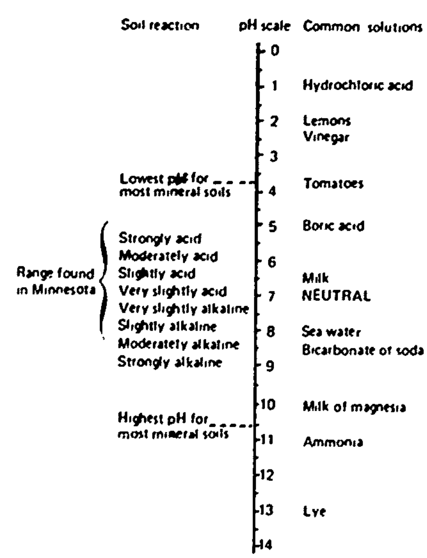


FIGURE 22. This scale shows soil acidity terms used in Minnesota and the pH values of some common solutions.

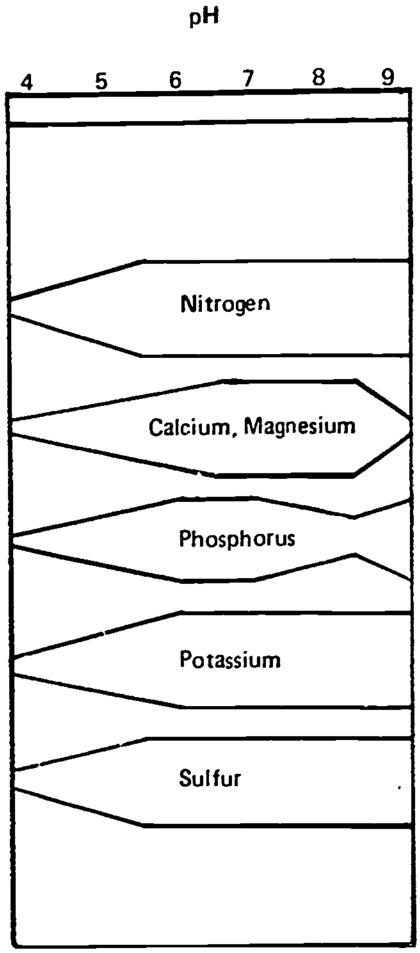


FIGURE 23. The width of each band shows the relative availability of some plant nutrients as they are influenced by soil reaction.

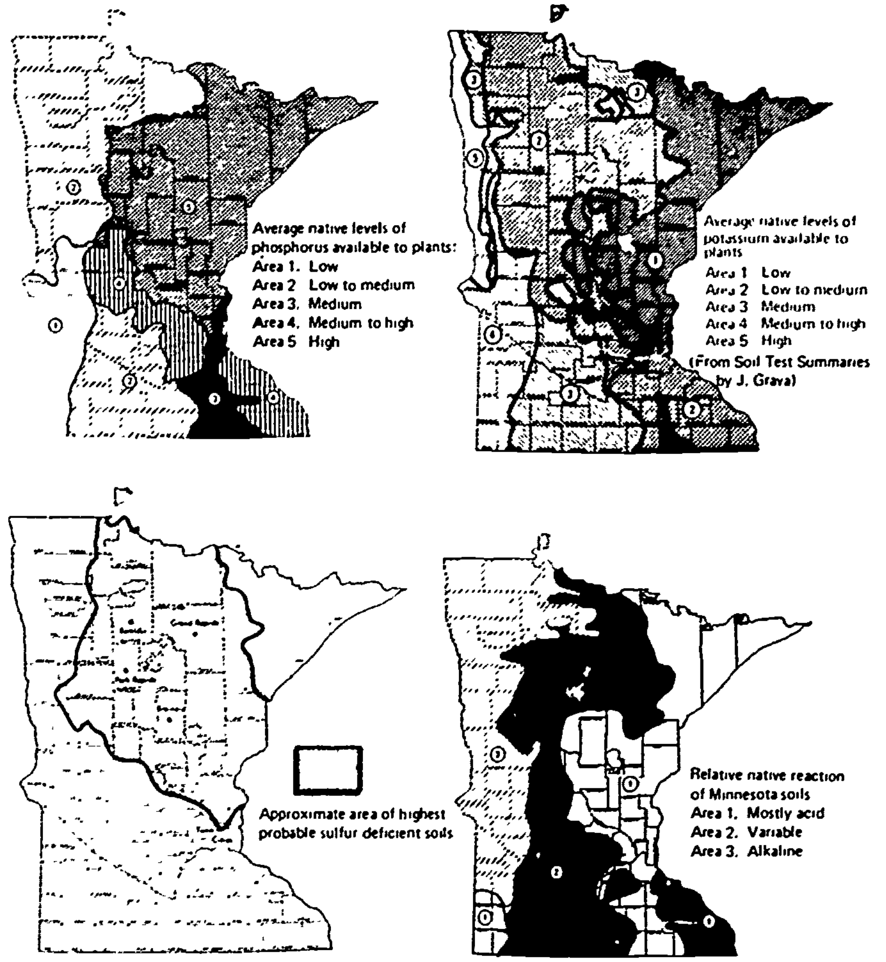


FIGURE 24. These maps show soil reaction and relative native levels of phosphorus, potassium, and sulphur available to plants in Minnesota.

it is alkaline. For example:

a pH of 7 represents $1 \times 10^{-7} \left(\frac{1}{10,000,000}\right)$ gram equivalents of hydrogen per liter.

a pH of 6 represents $1 \times 10^{-6} \left(\frac{1}{1,000,000}\right)$ gram equivalents of hydrogen per liter.

a pH of 5 represents $1 \times 10^{-5} \left(\frac{1}{100,000}\right)$ gram equivalents of hydrogen per liter.

A soil with a pH of 5 is 10 times more acid than one with a pH of 6. Minnesota soils vary from strongly acid (pH of 4.5) to moderately alkaline (pH of 8.5). The eastern two-thirds of Minnesota has mostly acid soils. The western is primarily alkaline.

Correcting soil acidity for plant growth is discussed in the section entitled Using the soil.

Soil fertility

Plants require 16 different elements. Carbon, hydrogen, and oxygen come from air and water. Plants obtain nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur in relatively large amounts from the soil, they are called macronutrients. Iron, manganese, boron, molybdenum, copper, zinc, and chlorine in soil are necessary in relatively small amounts; they are referred to as micronutrients. A fertile soil contains a sufficient supply of all these elements in an available form. Several factors affect the nutrient content of soil:

- dark-colored soils developed under prairie vegetation contain more natural nitrogen than soils developed under forests;
- coarse-textured soils, such as sands and sandy loams, usually contain less nitrogen and potassium than finer-textured loams and clays. The greater porosity of coarse-textured soils causes the elements to be rapidly leached into the subsoil beyond the reach of most plant roots;
- soil reaction influences the availability of many nutrient elements

The acid soils of eastern and northern Minnesota contain more available phosphorus than do the alkaline soils further west and south.

Micronutrient deficiencies occur to a limited extent in some Minnesota soils. Plant nutrients are discussed further in a following section, Using soil for agriculture.

TYPES OF SOILS IN MINNESOTA

Repeated glacial coverings of Minnesota left a wide variety of parent materials from which the state's soils were formed. There are differences in the bedrock materials carried in and also in topography, vegetation, and climate. Numerous soil types have been identified in Minnesota. These

SOILS OF MINNESOTA

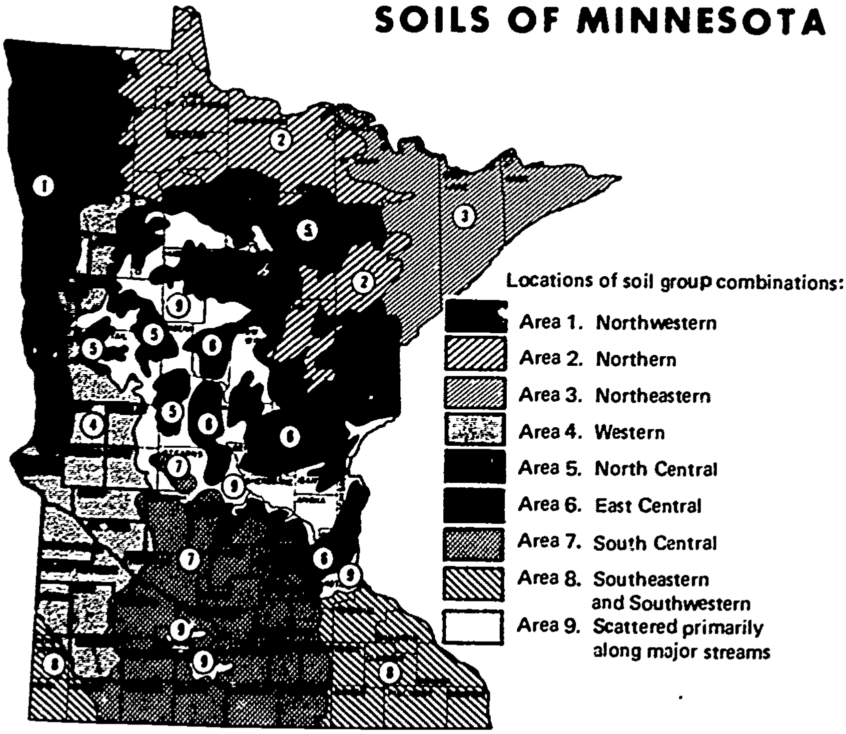


FIGURE 25. This map shows the locations of 15 broad soil groups in Minnesota.

FIGURE 26. (Above) Sunflowers are a common crop on the level land in northwestern Minnesota (SCS photo).

FIGURE 27. (Above) Large peat bogs are common in northern Minnesota (SCS photo).

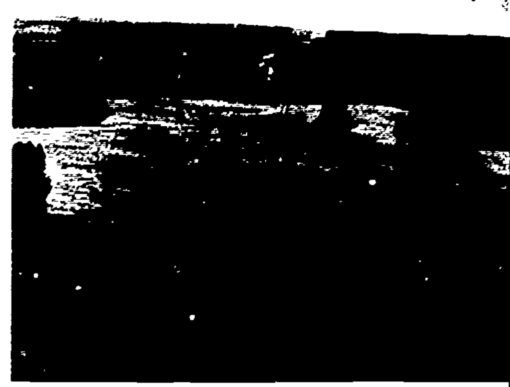


FIGURE 28. (Above) Northeastern Minnesota is mostly forested and has many lakes.

types have been classified into 57 different associations according to related characteristics such as adjacent location, amount of slope, and parent material. The associations have been combined into 15 broad soil groups considering location in the state, texture, and native vegetation. Several groups have been combined for the following description. Table 8 summarizes the distribution.

Northwestern area

The soils in and along northwestern Minnesota's Red River Valley comprise about 12 percent of the state's land area. Most of these soils were formed on the level bottom and beaches of glacial Lake Agassiz. The parent material is calcareous (contains much calcium carbonate); the native vegetation was prairie. The soil texture ranges from loam to clay. Both soil surface and internal drainage are distinct problems in the heavier soils. The soils are usually alkaline, medium to low in phosphorus, and high in potassium.

The Red River Valley is well-known for its farm products: small grains; sugar beets; and potatoes. Much of the area is unsuitable for septic tank sewage disposal drainfields. Poor internal drainage causes seepage problems in basements and foundation problems in building and road construction.

Northern area

Significant portions of north central Minnesota and Aitkin and St. Louis Counties were also covered by glacial lakes. These areas are generally level and include much peat. The texture of the mineral soils varies from sandy to clay. The area covers 13 percent of Minnesota's surface. The native vegetation on the upland areas was forest, and a light-colored soil developed. Some soils are drouthy. Others are poorly drained because of their clay subsoils or a high water table. All contain lime (calcium carbonate) in the parent material. The soils are medium to low in phosphorus and medium in potassium. The better areas produce small grains, legumes, potatoes, and forest products.

Northeastern area

Northeastern Minnesota soils, comprising 9 percent of the state, vary in texture from coarse to fine. The land is rolling to hilly with many outcroppings of basic igneous rock. Much of the area is a sandy-stony glacial till. Soils along the Canadian border and Lake Superior were formed from limy glacial lake clays. The vegetation was forest. The primary uses are forestry and recreation; there is very little agriculture.

FIGURE 29. (Below) Much of western Minnesota is covered with gently rolling glacial till (SCS photo).

FIGURE 30. (Below) Light-colored soils developed under the forests of north central and east central Minnesota (SCS photo).

FIGURE 31. (Below) Southern Minnesota's dark-colored soils are excellent for corn.

Western area

An irregular band of fertile, mostly prairie soils in western Minnesota extends from Clearwater County in the north to Nobles County in the south. It includes 11 percent of the state's surface. The slope of these soils varies from nearly level to rolling. The soils were developed from limy glacial till and are dark-colored. The texture varies from loam to clay loam; internal drainage ranges from good to poor. The soils are generally alkaline, medium to low in phosphorus, and medium to high in potassium. Corn, soybeans, and small grains are the predominant crops.

North central area

In north central Minnesota, there is a large area of light-colored loam to sandy loam soil that developed under forest vegetation. This area covers about 9 percent of Minnesota's surface. The parent material is a limy glacial till, and the area has an undulating to hilly topography. Lakes and poorly drained mineral and organic soils occupy the depressions and level areas. The soils are somewhat acid and medium to high in available phosphorus and potassium. The usual farm crops are legumes and small grains. Forestry and recreational enterprises are also common.

East central area

East central Minnesota has a wide variety of soils developed under forest vegetation. The parent material of this area, about 10 percent of the state, contains mostly limy grey and red glacial till and nonlimy red till with small lakelaid deposits and some outwash gravels. The topography ranges from level to rolling. Most of the soils are light-colored loams and sandy loams. There are some areas of silt loam, clay loam, and peat. Drainage varies from excessive to poor; however, most of the land is well-drained. The soils are usually acid, high in available phosphorus, and medium to low in available potassium. Dairying is the most common agricultural pursuit. Second growth timber, such as aspen, covers much of the area.

South central area

South central Minnesota has a large area of very productive agricultural soils. This area comprises 16 percent of Minnesota's surface. The topography is mostly level to gently rolling. Dark-colored soils have formed under prairie vegetation, and moderately dark ones were formed in the forest-prairie borders. Most of the soils are well-drained loams formed from limy glacial till. Depressional areas are clay loams having poor drainage. The topsoils are somewhat acid. The prairie soils are usually medium to low in available phosphorus; the prairie border soils are usually high. Most of the area contains medium amounts of available potassium.

Agriculture consists of cash grain crops, dairy, beef, and hog farming. (Cash grain crops are those sold rather than being fed to livestock on the farm where the grain was raised.)

Southeastern and southwestern areas

Soils formed from windblown parent material blanket parts of four counties in extreme southwestern Minnesota and parts of 13 counties in the southeastern part. The variety of characteristics requires three groups to be considered separately.

Portions of the four southwestern counties are blanketed by dark soils developed from a windblown limy silty material under prairie vegetation. The land is sloping and has good surface and internal drainage. The soil is slightly acid, medium to low in available phosphorus, and high in available potassium. Cash grain crops and livestock feeding predominate. The area comprises 1.5 percent of Minnesota's surface.

The southeastern counties having windblown soils may be divided into two groups. Eight counties on the east have silt loam soils that may be deep or shallow to bedrock. Slopes vary from gentle to steep. The light-colored soils were formed under forest vegetation; dark ones were formed under prairie. These soils are well-drained. Ten of the 13 southeastern counties also have shallow, windblown, silty soils over a medium-textured glacial till. The slopes are mostly gentle. Dark-colored soils formed under prairie vegetation; moderately dark ones formed in the forest-prairie border. Internal drainage varies from good to poor. These soils are usually acid, high in available phosphorus, and medium in available potassium. Cash grain, dairy, and livestock farming are important on all but the steep land. These soils make up 6.5 percent of Minnesota's area.

Scattered primarily along major streams

The melting continental glaciers left many areas of glacial outwash throughout Minnesota. When the edge of a glacier remained stationary for considerable time, large quantities of water from melting ice deposited well-sorted layers of sand and gravel. These outwash areas cover about 12 percent of Minnesota and are scattered throughout much of the state, especially along the major rivers. Prairie vegetation dominated the southern and western deposits. Forests grew on the northeastern and eastern ones. Topography varies from nearly level to rolling. Color may be dark or light, depending on native vegetation. Most of the surface soils are sandy; in many places, they are shallow over gravel. These soils are mostly drouthy, acid, high in available phosphorus, and medium to low in available potassium. These soils, unless irrigated, are usually unproductive for farming.

FIGURE 32. When irrigated, some sandy outwash plains in Minnesota produce excellent crops (SCS photo).

Table 8. Distribution of soil groups in Minnesota.

Area of Minnesota		Percent of state
Northwestern (Red River Valley)		11.6
Coarse to fine-textured prairie and organic soils of the glacial lake plains		
Northern		13.0
Coarse to fine-textured forest and organic soils of glacial lake plains		
Northeastern		9.1
Coarse to fine-textured forest soils and rock outcrops		
Western		11.3
Medium to fine-textured prairie and prairie border soils		
North central		8.5
Medium-textured forest soils		
East central		10.4
Coarse to fine-textured forest soils	1.8%	
Coarse to medium-textured forest soils	6.5%	
Fine-textured forest soils	2.1%	
South central		15.6
Medium to fine-textured prairie border soils	5.2%	
Medium to fine-textured prairie soils	10.4%	
Southeastern and southwestern		8.1
Windblown, silty forest and prairie soils (S.E.)	4.1%	
Windblown, medium-textured prairie and prairie border soils (S.E.)	2.5%	
Windblown, silty prairie soils (S.W.)	1.5%	
Scattered, primarily along major streams		12.4
Glacial outwash, coarse to medium-textured prairie soils	5.4%	
Glacial outwash, coarse to medium-textured forest soils	7.0%	
		100.0

Peat – organic soils

Fifteen percent of Minnesota's 80,000 square miles of land is peat (organic soil). Peat areas are scattered throughout Minnesota, but the largest deposits occur in the northern part of the state. Some characteristics of peat are much different from those of mineral soils. Organic soils contain more than 20-30 percent organic matter that formed during the past few thousand years. They formed from accumulations of aquatic vegetation in water. The water acted as a preservative, restricting oxidation of the dead material. Thus, peat accumulates in marshes. bogs, and swamps as the partially decomposed remains of pondweed, cattails, sedges, reeds, grasses, mosses, shrubs, and trees. The thickness of the deposits ranges from a foot or so to as much as 80 feet or more.

FIGURE 33. (Above) When drained, some peat soils are excellent for many vegetable crops (SCS photo).

FIGURE 34. (Below) Many peat soils produce excellent sod for new lawns (SCS photo).

To quite an extent, the original plants from which peats are formed determine the characteristics of these soils. Often, such plants as sedges, mosses, grasses, and cattails form very raw fibrous peat soils. Trees and brush become woody peats. Raw peat is usually tan, brown, or reddish brown. Decomposition of bog plant remains accelerates when the soil is drained or tilled, and continuing tillage reduces particle size. Particles in the upper layers turn darker with time, eventually becoming black. Peat soil is relatively light in weight. A cubic foot of peat soil contains from 4 to 30 pounds of dry matter; mineral soils average about 84 pounds of dry matter per cubic foot. An average peat soil can hold 6 to 10 times its dry weight in water; mineral soils have a water-holding capacity only one-fifth to two-fifths their dry weight. Thus, peat soil may hold about twice as much available water as the same volume of mineral soil. Most peat soils that have been drained are porous and easy to cultivate. When tilled, peat soils readily dry out and may drift in the wind. Dry peat burns readily, and peat fires are difficult to extinguish.

Peat soils vary widely in their soil reaction (acidity). Reaction depends on the vegetation, topography, and chemistry of mineral soils surrounding a bog. Peat in a depression may be alkaline or calcareous because the drainage waters flowing into the bog contain calcium from the surrounding land. Peat at bog surfaces on relatively level land may be acid because of much leaching. Peat soils, because of their high organic matter content, contain considerable nitrogen. They have low amounts of phosphorus and potassium available for plant use.

Peat soils that can be drained adequately are excellent for vegetables and for sod and grass seed production. Shallow peat over clay soil is well-suited for wild rice paddies.

Peat is a very unstable foundation for buildings and roads.

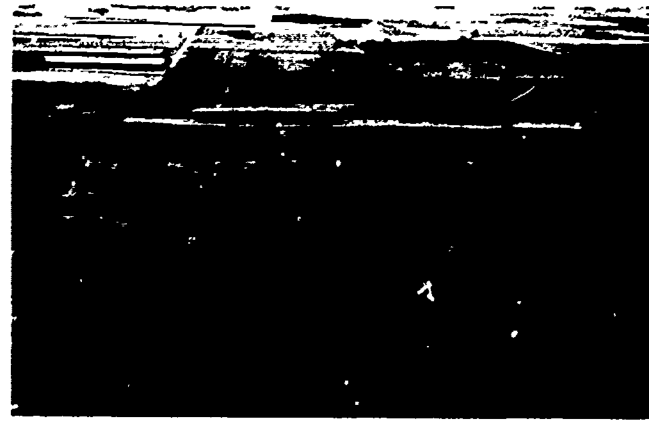


FIGURE 35. (Above) The long slopes of this Class II land have been terraced to control erosion (SCS photo). FIGURE 36. (Top right) Tile lines have been placed underground in this Class II land to improve drainage for crops (SCS photo). FIGURE 37. (Right) Strip cropping is used on this irregular Class III land to control erosion (SCS photo).

USING THE SOIL

Using soil for agriculture — capabilities and management

Farming is by far the most important use of Minnesota soil. About 28 million of Minnesota's 51.2 million acres of land are farmland. Crops are harvested from about 17.5 million acres. About 20 million acres of Minnesota's land are covered by forests. About 4.8 million acres of this forest land are on farms.

The Soil Conservation Service of the U.S. Department of Agriculture classifies agricultural land throughout the United States into capability classes. Classification is based on detailed soil surveys. individual soil mapping units are identified according to soil type and landscape. The eight capability classes show, in a general way, the soils and landscapes most suitable for agriculture. These classes are based on limitations and hazards of using each soil and the risk of land and crop damage when the land is not used within its capability and treated for proper erosion and soil moisture control.

About 4 percent (1.8 million acres) of Minnesota is *Class I*. Most of this is in the southern and southwestern parts of the state and is used as cropland. Class I lands have few limitations restricting their use for cultivated crops, pasture, woodland, and wildlife. They are deep, moderately well- to well-drained, and are easily tilled. They have good available-water capacity for plants and are either quite fertile or can be readily made productive. They are not subject to damaging overflows or flooding and have a favorable growing season for common field crops. Good management for intensive cropping may include liming, fertilizing, maintaining a high level of active organic matter, and rotating adapted crops.

About 35 percent of Minnesota (17.7 million acres) is *Class II* land. This land has a few limitations for cultivated crops, pasture, woodland, or wildlife. About two-thirds of this land is cropland, nearly 3 million acres of the Class II land is forested. Limiting features may include. gentle slopes, some susceptibility to erosion; somewhat shallow soil, less than moderate permeability, occasional damaging overflow or flooding; poor internal drainage, and a shorter growing season.

Good management of Class II land for continued high production and erosion control may require: crop rotations, including close-growing crops and/or legumes; tillage practices such as contour strips, strip cropping, contour tillage, and terraces; grassed waterways; and artificial drainage.

About 19 percent (9.9 million acres) of Minnesota's land is *Class III*. More than half of that (5.6 million acres) is cropland, 2.7 million acres is forested. Class III land, although similar to Class II, has more severe crop limitations. These limitations may be. moderately steep slopes, great susceptibility to erosion, continued imperfect internal drainage, even after tiling or ditching, or shallow soil over rock, sand, or gravel, or impervious soil layers that restrict root growth and the

FIGURE 38. (Above) This steeper-sloping Class IV land is used for pasture rather than for crops (SCS photo).

FIGURE 39. (Below) This steeply sloping Class VI land may be used for pasture but it should not be overgrazed (SCS photo).

FIGURE 40. (Above) Rough Class VII land is suitable for wildlife (SCS photo).

FIGURE 41. (Below) This Class VIII land has several rock outcrops. Such land may have aesthetic value (SCS photo).

soil's waterholding capacity for plants. Management practices needed for Class III land are similar to those for Class II land: however, they must be used more intensively.

About 16 percent (8 million acres) of Minnesota land is *Class IV* land. This land has very limited suitability for cultivated crops, such as corn and soybeans, because of these characteristics: steep slopes; severe susceptibility to erosion; severe effects of past erosion; shallow soil; low waterholding capacity for plants; and excessive wetness. Soil conserving tillage practices on this land are difficult to apply and maintain.

Class V land has little or no erosion hazard, but has other limitations severely restricting its use for cultivated crops. These limitations may be frequent overflow, stones, and ponded areas. Correction of these hazards is impractical, but such land is suitable for pasture, woodland, and wildlife. Four percent (2.2 million acres) of Minnesota's land is in this category.

Slightly less than 4 percent (1.8 million acres) of Minnesota land is considered *Class VI*. This land is generally unsuited for cultivation, but it is suitable for pasture or range, woodland, or wildlife food and cover. Limiting characteristics may be steep slopes, severe erosion hazard, effects of past erosion, stoniness, shallow soil, wetness or flooding, or drouthiness. Vegetative growth may be improved by seeding, liming, fertilizing, or water management.

Class VII land includes 7 percent (3.7 million acres) of Minnesota's land area. The limiting characteristics are similar to those for Class VI but are more severe. It is impractical to use vegetative improvement practices. If this land is carefully managed, it can be used for grazing, woodland, or wildlife.

About 1 percent (700,000 acres) of Minnesota land is *Class VIII*. This land is not suitable for commercial plant production because of its erosion hazard, wetness, stoniness, or drouthiness. Rock outcrops, sandy beaches, marshes, river wash, mine tailings, and other nearly barren lands are included in Class VIII. The land may have wildlife and aesthetic values.

The amounts of Minnesota land in the eight capability classes are summarized in table 9.

Table 9. Capability of Minnesota land for agriculture.

	Minnesota Land	
Class	Millions of acres	Percent of state
I	1.8	4
II	17.7	35
III	9.9	19
IV	8.0	16
V	2.2	4
VI	1.8	4
VII	3.7	7
VIII	0.7	1
*Not classified	5.4	10
	51.2	100

*consists of small water areas less than 40 acres in size, urban and built-up land, and federally owned, noncrop land.

The effect of changing soil characteristics on capability class is illustrated in the following table.

Soil well-suited for cultivated crops is nearly level to gently sloping and has medium to moderately coarse surface texture, a depth of at least 3 feet for root growth, no flooding, and good to moderately good internal drainage. Soil well-suited for permanent grass pasture would be nearly level to moderately steep or hilly and have medium to moderately fine surface texture, a depth of at least 3 feet, at least moderately good drainage, and flooding not more than four times annually for short periods.

There are numerous practices that can be used to overcome undesirable soil features.

Level or low land having *poor surface drainage* and *subject to flooding* may be ditched, reshaped (formed), or provided with surface inlets extending to tile lines to hasten the removal of excess surface water.

Sloping land with erosion hazards may be terraced to shorten the effective length of slope and to lead surface runoff to grassed waterways or tile lines. Contour tillage helps control erosion on even or regular slopes. Some slopes are too irregular for contour farming with modern equipment. Staying on the contour would require turns too sharp to make with today's machinery. In such cases, alternating strips of close-sown and row crops are farmed across the general slope. The same practice helps control wind erosion. On steeper irregular slopes, small grains and hay are grown almost continuously to control erosion.

Soil texture influences available water capacity and soil aeration, thereby affecting plants, seedbed preparation, erodibility, irrigation, and other factors. On a large scale, changing soil texture is even more impractical than changing the slope. Farmers should choose crops and practices to fit the texture.

The *depth of soil favorable to root growth* and its influences in agriculture have been discussed previously. Crops do vary considerably in their root depth. Although most roots are in the upper 1 foot of soil, field corn roots commonly grow to 5 feet deep; alfalfa roots under arid conditions may go down 20 feet.

The value of *organic matter* in agriculture has been recognized for centuries. Farmers maintain organic matter levels in soil by using soil-conserving tillage practices, spreading manure, and incorporating crop residues.

Many soils are too wet for good crop growth. Where it is practical, farmers use underground tile lines or open ditches to remove excess water.

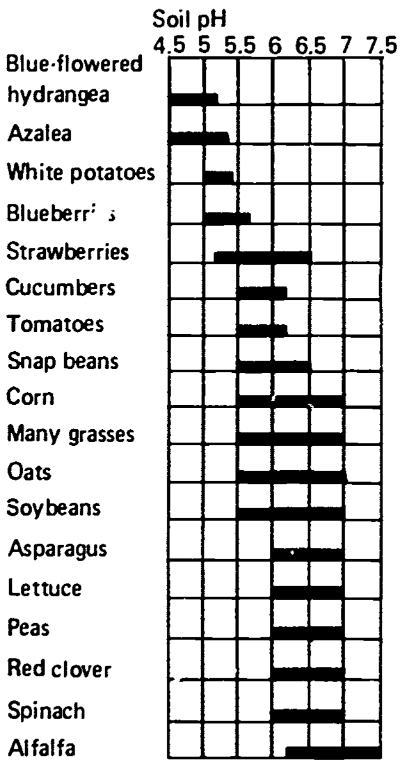
Soil reaction (acidity and alkalinity) is a major factor in plant growth. Some plants, like alfalfa, cannot tolerate acid soils; others, such as blueberries, thrive on acid soil. Most plant species prefer a soil that has nearly neutral reaction. Soil reaction influences:

- adapted crops and their productivity;
- amount of lime needed on acid soil to grow other crops productively;
- efficiency of nutrients applied as fertilizer;
- amount of "mineral" nutrients (nitrogen, phosphorus, potassium, micronutrients) available for plant use.

Maintaining a near neutral pH is important on Minnesota's acid-prone soils. Farmers have their soil tested and may apply as much as 6 tons of

Table 10. Changing soil characteristics as they influence land capability class.

Characteristic	Class I	→ Class VIII
Slope	nearly level (0-2%) →	increasing steepness
Degree of past erosion	some accumulation to 1/3 of original soil remaining →	increasing past erosion
Erosion hazard	slight →	increasing hazard
Depth of soil	more than 6 feet →	decreasing depth
Available waterholding capacity	good to very good (9 inches or more) →	decreasing capacity
Internal drainage	well to moderately well-drained →	poorer drainage
Permeability	moderate to moderately rapid (0.6 to 6.0 inches per hour) →	slower permeability
Flooding or overflow	none →	increasing frequency or duration
Climate	satisfactory →	shorter season, lower temperatures



(Adapted from SOIL, 1957 Yearbook of Agriculture, U.S.D.A.)

FIGURE 42. Plant species have varying tolerances to soil acidity.

ground limestone per acre to correct acidity and raise the pH from 5.7 to 6.5. Alkalinity is not a major problem in Minnesota soils, although in some western Minnesota locations, free lime in the root zone inhibits the uptake of iron by soybeans and causes plants to turn yellow.

Farmers can meet most *plant nutrient needs* by applying commercial fertilizers and/or manure. The primary elements added are nitrogen, phosphorus, and potassium. The amounts needed depend on the level of available nutrients in the soil, the productive capacity of the soil, the crop to be grown, the yield level desired, and similar factors. For example, a southern Minnesota farmer wants to grow corn for the second consecutive year on soil testing low in phosphorus and medium in potash. He would apply 120 pounds of nitrogen, 50 pounds of available phosphate, and 25 pounds of potash per acre of land. A farmer in northwestern Minnesota wishing to grow wheat in a soil medium in phosphorus and high in potassium would apply 60 pounds of nitrogen and 30 pounds of phosphate per acre and no potash.

The major elements in plants are carbon, hydrogen, and oxygen. Plants obtain these elements from water and carbon dioxide. Nitrogen is a constituent of every living cell; it is a part of all proteins, chlorophyl molecules, and some enzymes. Phosphorus is also a part of every cell. It is important in plants' energy transformation from starch to sugar. Potassium is essential in cell metabolism; it has specific roles in plant functions such as respiration and transpiration but is not a part of plant compounds. Calcium is a part of cell walls. Sulfur is a part of some amino acids. Several of the micronutrients – magnesium, iron, manganese, copper, and zinc – are important in plant enzyme systems. Enzymes facilitate or promote complex chemical reactions in plants but do not become a part of the resulting compounds.

Micronutrient (nutrient elements required by plants in relatively small amounts) deficiencies for agricultural crops occur to a limited extent in some Minnesota soils. On some sandy soils low in organic matter, a boron deficiency limits the growth of some crops such as alfalfa and sugar beets. Zinc deficiencies have occurred in corn and other crops on poorly drained soils high in lime. Additions of magnesium and molybdenum have been beneficial on some acid soils. Additional iron has improved crops on some alkaline soils.

Many plant species show specific visual symptoms when certain nutrients are deficient in the soil and, therefore, in the plant. For example, the bottom leaves of corn deficient in nitrogen will be yellowish down the middle of the leaf. A potassium deficiency produces yellow edges on corn leaves. Phosphorus deficiency causes purplish leaves. A deficiency of any nutrient limits the growth of plants.

Farmers may determine fertilizer needs by having their soil tested by a reliable testing laboratory. Such a laboratory will also make recommendations for the specific crop a farmer wishes to grow.

Suitability and use of soil for other purposes

When people build a community, they change the land. Buildings, sidewalks, streets, and parking lots cover as much as half of the land in a community. Most precipitation falling on those areas is diverted by gutters and sewers into streams and lakes. During building construction, heavy equipment removes absorbent topsoil and compacts the remaining surface, thus reducing the ability of future lawns to absorb rainwater. Wise community planners and developers carefully consider these effects as they plan and build a community.

In general, soil that is ideal for common agricultural crops is ideal for *home lawns, gardens, shrubs, and trees*. The slope will be nearly level to gently sloping (0 to 6 percent). The lawn will have a slope of at least 1 percent away from the house so water will not seep into the basement. Gentle slopes are less subject to erosion. There is more time for water to soak into the ground for plant use, resulting in less surface runoff. Lawns are more difficult to seed on steep slopes; to resist erosion, new turf may need to be staked or otherwise anchored until the roots develop more fully.

The texture of ideal soil will be between a clay loam and a sandy loam. Such soils can hold considerable moisture for plant use. They are permeable so surface runoff is not excessive and so aeration is adequate for plant roots. Finer soils have poor aeration; coarser soils are drouthy and need to be watered more often. A good soil surface or seedbed is important for a lawn or garden. Sandy soils seldom crust on the surface, but they dry out rapidly. Clay soils remain moist longer, but they easily form a surface crust that hinders the emergence of tender young plants. This is especially true if the soil's organic matter content is low.

For the most favorable root conditions, soil depth should be 4 to 6 feet above compacted soil layers, rock, the water table, or porous gravel and sand. Such a depth provides plants with sufficient air, water, and nutrients.

Dark-colored topsoil 10 to 12 inches deep indicates a high organic matter content. Organic matter helps the soil maintain a crumblike structure that resists erosion, enhances water infiltration, and promotes aeration. Dark-colored soils also have more nitrogen available for plants. Somewhat red or yellow subsoil indicates better internal drainage and aeration than occurs where subsoil is grey.

Lawn grasses tolerate moderately acid conditions down to a pH of 5.5. If lawns are more acid than this, they will benefit from an application of finely ground agricultural limestone. Lime may be spread at the rate of 75 pounds of finely ground limestone per 1,000 square feet of lawn. Most garden crops are more productive on soils that are neither very acid nor very alkaline. Soil having a pH lower than 6.0 can be improved by spreading limestone at a rate of about 200 pounds per 1,000 square feet of garden.

Home lawns and gardens may benefit from applications of commercial fertilizer just as agricultural crops do. Soil beneath a lawn or garden may vary considerably in texture and other features because of excavation and filling during house construction. Reliable soil tests help determine needed plant nutrients.

University of Minnesota publications contain detailed recommendations for improving soil reaction, fertility, organic matter, and other lawn and garden soil characteristics.

Soils well-suited for homes, gardens, and cultivated crops are also well-suited for *forest trees*. However, plant nutrient and water requirements are not as great for trees as for cultivated crops. Soil for deciduous trees should be nearly level to moderately steep or hilly, have a medium to moderately fine texture, be at least moderately well-drained and have a rooting depth of at least 20 inches. Conifers grow better on somewhat coarser-textured soils, need better drainage, and require less moisture than do deciduous trees.

The steepness of slope is important for timber production. Steepness and direction of slope (aspect) affect the soil temperature which, in turn, influences the kinds of trees present and their growth rates. Slope also affects the ease of harvesting. Logging trails and bare cutover areas on the steeper slopes readily erode until they are again protected by vegetative cover.

Soil texture influences forest tree species and their rate of growth or productivity in much the same way as soil texture affects lawns, gardens, and

FIGURE 43. (Above) Forest trees tolerate a fairly wide range of soil conditions (SCS photo).

FIGURE 44. (Below) Because they grow slower and, therefore, fuller, pines grown on sandy soils make better Christmas trees than do pines grown on finer-textured soils (SCS photo).

agricultural crops. Maple and basswood do not grow well on sandy soils; red pines grow poorly, if at all, on waterlogged soils. Pines grow slower on sandy soils than on loam soils. Those grown on sandy soils are then better suited for Christmas trees because their sets of branches are closer together on the trunk.

Tree growth reflects soil fertility. Fertilizer applications have not produced economic gains on Minnesota forest land, however.

Soil well-suited for homes, gardens, crops, and forest trees is also well-suited for *upland wildlife*. If their other needs are also met, wildlife populations will be in direct proportion to the production of their foods on the land. Soil characteristics considered good for upland wildlife habitat are: slopes ranging from nearly level to steep; moderately coarse to moderately fine texture; infrequent flooding; at least moderately good drainage; at least 20 inches of rooting depth; and a fair amount of water available for plant growth (9 inches available water capacity). Wetland wildlife use poorly drained land which has at least 3 feet of water continuously and open water (free from emergent vegetation) all summer.

Homeowners want to avoid water in their basements, cracked foundations, uneven floors, sticking doors, and similar problems. Better *homesites* are on nearly level to gently sloping land having medium- to coarse-textured subsoil 5 feet or more above bedrock or the water table. Homesites should be in locations that will not flood. Basements built on fine-textured soils may have frequent seepage problems. It is easier for the water to seep through the wall than to move in other directions through the soil. Tile drains may be laid along the outside of the house foundation's footings, and coarse aggregate may be put along the outside of the basement walls to intercept this drainage. There must be a suitable outlet or a sump pump, however.

Some clay soils swell considerably when they are wet and shrink when they are dry. Buildings on these soils frequently develop cracked walls and foundations and uneven floors, door sills, and windows. Stronger foundations and footings can partially alleviate this problem.

A soil well-suited for a *home sewage disposal* drain or filter field (also called soil absorption system) will have less than 10 percent slope, have medium to moderately coarse texture, be well-drained both on the surface and internally, be 6 feet or more in depth to bedrock or water, and have no flood hazard. Design is more complex and installation costs are greater on slopes exceeding 10 percent. Where the land slopes more than 18 percent, the sewage may actually seep to the surface of the ground and flow downhill.

The subsoil percolation rate is the most critical factor for sewage disposal. The soil must absorb at least 1 inch of water per hour. Percolation rates for drainfields are usually expressed as minutes per inch. The maximum time is 60 minutes per inch of water. A sand or gravel soil may have a percolation rate of less than 10 minutes per inch of water. A silty clay loam subsoil underlain by loam material may require 1 hour to absorb 1 inch of water.

Slope and percolation are not the only considerations. Rapid percolation may cause pollution of underground or nearby surface water. At least 4 feet of earth must be between the bottom of the drainfield trench and the water table or impenetrable layers such as rock.

Highway and street planners who design heavily traveled roads must understand the engineering properties of soils. *Streets* are most easily built and maintained where slopes are less than 6 percent and do not flood. Moderately coarse to coarse soil 5 feet above bedrock and the water table will provide good internal drainage and be free of shrink-swell problems. On steeper slopes, roads must be cut through hills, and low areas must be filled to reduce the slope. Clay soils, with their high waterholding capacity and low permeability, are not desirable. Road contractors may excavate the roadway and haul in coarser fill from which excess water can drain. Otherwise, the roadway may become uneven, frost boils may develop during the spring, and the road surface may collapse under heavy traffic.

Peat soils, because of their poor engineering qualities, are a problem to Minnesota road builders. They may

FIGURE 45. (Opposite page, left) These homes are on the floodplain of the Minnesota River. FIGURE 46. (Middle) Drain tile is being laid along the outside of the house foundation to intercept possible basement wall seepage (SCS photo). FIGURE 47. (Right) This house was built on soil not suitable for buildings (SCS photo).

FIGURE 48. (Opposite page, left) A drainfield is being installed here to distribute household sewage liquids throughout a large area of the soil. FIGURE 49. (Middle) The drainfield pipe has small holes in it. The rock surrounding the pipe exposes more soil surface area to the effluent. FIGURE 50. (Right) Frost boils may develop in roads built on poorly drained soils (SCS photo).

FIGURE 51. (Opposite page, left) The peat being removed for the new roadbed will be replaced with firm soil material (Minn. Hwy. Dept. photo). FIGURE 52. (Middle) Controlling erosion on new road slopes and ditches is difficult. FIGURE 53. (Right) Until grass is established, a straw mulch is used to temporarily control erosion along new roads.

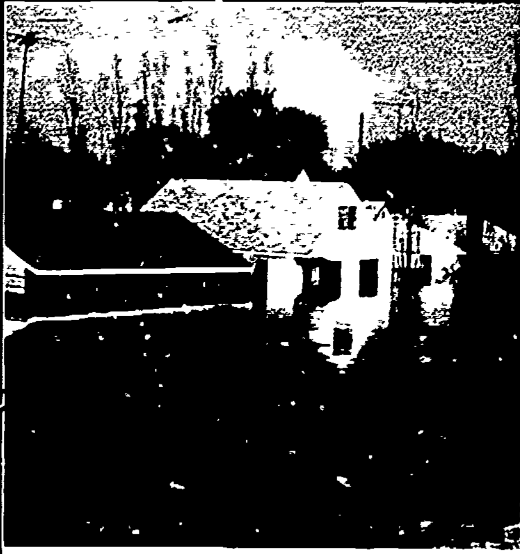


FIGURE 54. (Immediate right) Overused bike trails can become deep gullies, disfiguring the landscape (SCS photo).

FIGURE 55. (Opposite page) Excessive use damages campsites. Vegetation is difficult to reestablish.

plan routes around bogs, or they may excavate the peat and replace it with firm soil material.

During road construction, precautions must be taken to control erosion along the right-of-way. Otherwise, heavy rains may damage the road while it is being built. Road ditches and slopes must be designed to prevent erosion. Frequently, structures such as drop spillways and terraces are used to control erosion. Vegetation is the best erosion control on roadside slopes. Where soils are suitable, road builders may lay sod or plant grass. They may use huge blowers to spread a straw mulch for temporary protection until new grass grows. A wet mixture of wood fibers, fertilizer, and grass seed is blown onto hillsides that are too steep for planting machinery.

Utility contractors – such as water, sewer, and other pipeline installers – face some of the problems road builders do. Pumping stations are necessary to move liquids over hills. Operating the construction and maintenance equipment and moving the construction supplies over steep slopes is very costly. Controlling erosion during and following construction can be a serious problem. Fine-textured soils increase the cost of construction, especially during wet weather. Very sandy and gravelly soils do have one undesirable construction feature. The sides of deep excavations must have relatively flat slopes or be supported by retaining walls to avoid caving or slides.

Minnesota land offers many opportunities for a wide variety of *recreational activities* in addition to hunting and observing wildlife. More than one-third of the land area is not suited for agricultural crops. Most of this area is forested, and much of it is interspersed with many lakes. Suitable sites for lakeside cottages, resorts, campgrounds, trails, and the like are abundant. However, intensive use of these areas must be limited to prevent degradation of the land. Recreational areas are usually located on steep slopes and/or sandy soils not well-suited for cultivated crops. Hence, they do not produce luxuriant growths of natural vegetation either. When campgrounds, primitive campsites, and trails are overused, the resulting trampling or packing from too many feet and wheels destroy the protecting vegetative cover. Less water soaks in, and more runs off, carrying soil with it. Reestablishing a good grass cover on poorly suited sites or under trees is very difficult.

Septic tank drainfield requirements for a lake cottage are similar to those for any other home. Home sewage frequently finds its way into the lake as it flows over fine-textured soils or percolates too rapidly through coarse-textured subsoil.

Minnesota soil varies greatly from place to place. There are many combinations of soil characteristics. Some combinations are good for homesites, lawns, gardens, agricultural crops, or forests. Others are good for ducks and other waterfowl. Community-minded citizens and community planners should understand the soil. Flood plains and filled-in swamps are poor locations for homes; there is less damage if they are used as parks. Widespread removal of protective cover on soil being developed for housing, commerce, or industry may result in water erosion and downhill or downstream sedimentation and wind erosion. Putting sewer and water lines on hilly land or in bedrock can be costly to the taxpayer. We all use the soil in some way, whether watering the lawn or building a freeway.

There is a wealth of information about Minnesota soils. The tools are available for Minnesota citizens to know how to match our needed land uses with the types of soil we have. We can use our land properly and avoid degrading our environment and resources if we learn the basics about soils and use them accordingly.

REFERENCES

1. CHARACTERISTICS OF SELECTED HORIZONS FROM 16 SOIL SERIES IN MINNESOTA, Technical Bulletin 272, 1970. D.J. Pluth, R.S. Adams, Jr., R.H. Rust, and J.R. Peterson. University of Minnesota Agricultural Experiment Station.
2. FERTILITY STATUS OF MINNESOTA SOILS AS SHOWN BY SOILS TESTS, Miscellaneous Report 56, 1964. John Grava. University of Minnesota Agricultural Experiment Station.
3. FERTILIZING THE HOME LAWN AND LANDSCAPE MATERIALS, Soils Fact Sheet No. 7. L.D. Hanson and C.G. Hard. University of Minnesota Agricultural Extension Service.
4. GUIDE FOR INTERPRETING ENGINEERING USES OF SOILS. USDA Soil Conservation Service. U.S. Gov't. Printing Office, Washington, D.C.
5. GUIDE TO COMPUTER PROGRAMMED SOIL TEST RECOMMENDATIONS IN MINNESOTA, 1974. Special Report 1, January 1974. William E. Fenster, Curtis J. Overdahl, Charles A. Simkins, Bob McCaslin, and John Grava. University of Minnesota Agricultural Extension Service.
6. GUIDE TO USE OF SINGLE SHEET SOIL SURVEY INTERPRETATIONS. MN-SOILS-2. USDA Soil Conservation Service.
7. LAND CAPABILITY CLASSIFICATION, Agric. Handbook No. 210. 1961. U.S. Dept. of Agriculture, Soil Conservation Service. U.S. Gov't. Printing Office, Washington, D.C.
8. LIME NEEDS IN MINNESOTA, Soils Fact Sheet No. 10, 1968. W.E. Fenster, C.J. Overdahl, and J. Grava. University of Minnesota Agricultural Extension Service.
9. LIMING MINNESOTA SOILS, Extension Folder 210. 1970. John Grava, C.J. Overdahl, and W.E. Fenster. University of Minnesota Agricultural Extension Service.
10. MINNESOTA SCIENCE, Volume 23, No. 3, April 1967. University of Minnesota Agricultural Experiment Station.
11. MINNESOTA'S ROCKS AND WATERS, Minnesota Geological Survey, Bulletin 37. George M. Schwartz and George A. Thiel. University of Minnesota Press, Minneapolis, MN. 1963.
12. MINNESOTA SOIL AND WATER CONSERVATION NEEDS INVENTORY. 1971. Minn. Conservation Needs Committee.
13. THE NATURE AND PROPERTIES OF SOILS, Seventh Edition. Harry O. Buckman and Nyle C. Brady. The MacMillan Co., N.Y. 1969.
14. RESOURCE CONSERVATION GLOSSARY. Soil Conservation Society of America, Ankeny, Ia. 1970.
15. SOILS OF MINNESOTA, Extension Bulletin 278, June 1963. H.F. Arneman, University of Minnesota Agricultural Extension Service.
16. SOILS OF THE TWIN CITIES METROPOLITAN AREA, Extension Bulletin No. 320. Lowell D. Hanson, et al. University of Minnesota Agricultural Extension Service. (out of print)
17. SOIL, THE 1957 YEARBOOK OF AGRICULTURE. U.S. Dept. of Agriculture. U.S. Gov't Printing Office, Washington, D.C.